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CONTENTS

Chemical Factors in Nutrition 1
LAFAYETTE B. MENDEL
Internal Combustion Engines in Marine Service 11
CHARLES EDWARD LUCKE
Leonardo da Vinci—Natural Philosopher and Engineer 47
JOHN W. LIEB
Thermal, Electrical and Magnetic Properties of Alloys 69
ALPHEUS W. SMITH
Notes from the U. S. Bureau of Standards 107
Notes from the Nela Research Laboratory 109
Notes from the U. S. Bureau of Chemistry 113
Notes from the Research Laboratory, Westinghouse Electric and Manufacturing Company 115
Notes from the U. S. Bureau of Mines 117
The Franklin Institute Notes 121
Book Notices 132
Publications Received 137
Current Topics 46, 106, 116, 139
Announcements . . . . . ix–xii

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CHEMICAL FACTORS IN NUTRITION.*

BY

LAFAYETTE B. MENDEL, Ph.D., Sc.D.

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WHEN the food which we ingest starts on its way along the path of the alimentary tract it is ordinarily regarded as having entered the body. It does, in truth, disappear from sight as soon as it has passed beyond the mouth and into the deeper recesses of the organism; but every one who is familiar with the structure of the long gastro-intestinal tube—the digestive canal—realizes that the walls of the latter offer a pronounced barrier to the ready transport of the swallowed food materials to the various tissues and organs where it may be needed. To follow the nutrients into the stomach and upper intestine is comparatively easy; far more difficult, however, is the task of tracing their passage through the thick walls of the alimentary tract into the lymph and blood-streams wherein they are distributed far and wide in the body.

Insoluble food particles obviously cannot permeate the mucous membrane that lines the enteric tract. The older physiologists, who concerned themselves not at all with the problem of how such solid nutriment is made available, were content to assume that in some way it must become soluble so that it can filter or diffuse through the gastro-intestinal wall. Some sort of digestion was thus conceived to be essential to absorption in the case of insoluble products such as much of an ordinary meal represents. For a long time it was vigorously debated whether digestion in the

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stomach, and perhaps beyond, was not secured by mechanical trituration of the food or by some fermentative processes. It redounds to the credit of the progress of science in America that this country early furnished one of the great classics in the study of physiology of digestion. The pioneer investigations of Dr. William Beaumont on Alexis St. Martin, the man with "the lid on his stomach," helped to elucidate the nature of the gastric juice and establish the fact that it is an "agent of chymification" which "acts as a solvent of food and alters its properties." Experiment thus replaced conjecture.

The familiar foodstuffs—the proteins, fats and carbohydrates—which in large measure compose our food, are not simple chemical substances; they are for the most part rather complex compounds. With the development of the physiological chemistry of digestion has come the growing recognition that all the foodstuffs not merely are dissolved, but are further chemically disintegrated before they experience absorption. This profound cleavage of the nutrients into relatively simple fragments is accomplished by the unique potency of the digestive juices. In my own student days it sufficed to believe that the digestion of proteins, accomplished by the proteolytic enzymes or ferments of the gastric and pancreatic secretions, transformed the albuminous substances into proteoses and peptones, still essentially protein in nature except for a greater diffusibility, and perhaps to a smaller extent into a few then recognized amino-acids. Foster's "Text-book of Physiology," a popular treatise of a quarter of a century ago, stated:

> In all events the greater part of the proteid material of the food enters the blood as proteid material either as peptone or in some other form, and is carried as proteid material to the tissues. * * * The evidence as far as it goes tends to show that the metabolism of proteid is very complex and varied, that a large number of nitrogen-holding substances make a momentary appearance in the body, taking origin at this or that step in the downward steps of katabolic metabolism and changing into something else at the next step, and that the presence in various parts of the body and even in the urine, in small quantities, of so many varied nitrogenous crystalline substances, forming a large part of what are known as extractives, has to do with this varied metabolism. Possibly the transformations by which nitrogen thus passes downward take place to a certain extent in such organs as the liver and the spleen, which are remarkably rich in these extractives. But the whole story of proteid metabolism consists at present mostly of guesses and of gaps.

To-day there is added the knowledge of the further peculiar proteolytic power of the intestinal secretion, with the possibility

of a more or less complete disintegration of proteins into their constituent amino-acids prior to absorption. So, too, the fats are digested, not merely dissolved or absorbed in particulate form; and the carbohydrates pass through the alimentary wall as simple monosaccharide compounds. The true nutrient units discoverable after absorption in the blood-stream are comparatively simple chemical compounds rather than the complex food substances which we ordinarily ingest. Hence there is a significant truth in the recent statement that "the tissue cells never know the food which we eat." Digestion, profound in its chemical cleavages, is recognized as the indispensable forerunner of absorption.

The outcome of the digestive disintegration of the ingested foodstuffs is, therefore, somewhat different from what one would have assumed only a few years ago. The ultimate sources of energy for the organism start as relatively simple chemical compounds on the path of distribution to the places where they are required for fuel or constructive enterprises. Amino-acids, other nitrogenous units like purins or nucleosides, simple sugars, and fats represent the particular types of matter that enter the transportation routes of the circulation. Sometimes they are built selectively into desired structures—into tissue fabrics or components of secretion; sometimes they are stored in special depots as fat or glycogen or protein to await a future demand for these reserves; sometimes they are at once consumed or, to quote the term used by the physiologist, they are metabolized.

The various aspects of life, like other activities in the world about us, represent a transformation of matter and energy. Our organism builds up and in turn wears out its structural parts, it utilizes food fuel somewhat as non-living mechanisms employ coal, wood, oil or gas. From this general standpoint the preceding review of the preparation of our food for distribution and subsequent use is not difficult to appreciate. It is only when the subtle details are contemplated that the innumerable intricate problems of nutrition present themselves. How does the organism build the absorbed nutrient units into suitable anatomical structures, or how does it transform them so that work is done and heat produced? The analogies of the steam engine with its fire box and fuel and air supply leave us in the lurch when we attempt to institute a strict comparison with the living organism. Indeed it may as well be admitted that the complete history of the physio-

logical metabolism of matter is still obscure and unrevealed. From time to time, however, new details have come to light, revealing some of the secrets of the chemical processes upon which life depends. Let us turn our attention to a few of these.

There are organisms which can satisfy their biological needs with a comparatively few substances of relatively simple character. Thus the yeast plant can be made to grow and complete its life cycle in a medium that furnishes only comparatively simple compounds—a little pure sugar, nitrogen in the form of ammonium sulphate, along with phosphates and chlorides of potassium, calcium, and magnesium. Development under these circumstances means profound chemical synthesis. The yeast organism builds up highly complex proteins, fats, carbohydrates, nucleic acid and presumably a multitude of as yet unrecognized compounds into the tiny cells that seem so simple and relatively undifferentiated to an observer through the microscope. Plants in general possess such remarkable powers of synthesis—mysterious and never failing in their wonders. The carbon dioxid of the air suffices to furnish carbon for most elaborate structures. Such well-recognized atmospheric sources of plant nutriment were scarcely dreamed of by the older investigators who searched for a "principle" of vegetation to account for the phenomena of soil fertility and plant growth. Van Helmont considered he had found it in water, and thus records his famous Brussels experiment:

> I took an earthen vessel in which I put 200 pounds of soil dried in an oven; then I moistened with rain water and pressed hard into it a shoot of willow weighing 5 pounds. After exactly five years the tree that had grown up weighed 169 pounds and about 3 ounces. But the vessel had never received anything but rain water or distilled water to moisten the soil when this was necessary, and it remained full of soil which was still tightly packed, and, lest any dust from outside should get into the soil, it was covered with a sheet of iron coated with tin, but perforated with many holes. I did not take the weight of the leaves that fell in the autumn. In the end I dried the soil once more and got the same 200 pounds that I started with, less about two ounces. Therefore the 164 pounds of wood, bark, and root arose from the water alone.

The animal organisms, on the other hand, are not endowed with capacities for constructive work equal to those possessed by plants. It is not merely nitrogen, carbon and oxygen in some simple groupings that they require to be elaborated by them synthetically into brain and muscle and gland components. The powers of synthesis in animals are limited. Bathed though they

continually are in a sea of nitrogen, they cannot utilize it to produce nitrogenous tissues. There are certain structural units which the animal cannot manufacture *de novo*. Unless these are supplied as such, growth, tissue construction and repair are limited to the available supply of the essential parts.

The evidence for this conclusion forms a comparatively recent chapter in the study of nutrition. The nitrogenous needs of an animal can be supplied by the inclusion of protein in the diet. The newer chemistry of the proteins has brought unexpected revelations regarding their intimate structure and has thereby completely altered the traditional views regarding their physiological behavior. It has been demonstrated that, in general, the proteins are complexes which yield eighteen or more amino-acids that have become prominent items of interest to the student of nutrition. The proteins from different sources, and likewise the different proteins from a single plant or animal tissue, may vary in respect to the proportions of the characteristic amino-acids—the constructive units or "building stones" out of which they are built up. Some fail to yield one or more of the amino-acids usually obtainable from proteins. In this sense they are sometimes spoken of as "incomplete" proteins. For example, of the usually obtained representatives, the protein zein of the maize kernel fails to yield either glycocoll, lysine, or tryptophane; the gliadin of wheat is comparatively poor in its contribution of lysine and extremely rich in the glutaminic acid group; the gelatin derived from connective tissue lacks the tyrosine, tryptophane and sulphur-containing cystine groups.

With the possibility of such inequalities in the protein intake presented to the organism, how are we to conceive of the production or maintenance of blood- or muscle- or nerve-protein having the unvarying and specific chemical character that biological experience leads us to expect? For the answer to this question the modern chemistry of digestion has given a clue scarcely anticipated a generation ago. It has demonstrated that the various proteins are disintegrated in the digestive processes into their constituent amino-acid groups. It is, for the most part at least, these amino-acids rather than proteins *per se* that are absorbed and represent the ultimate alimentary contribution from the ingested proteins. The amino-acids are the fragmentary units in the form of which the albuminous intake is distributed throughout the body. From such fragments every individual tissue can select the con-

structive "building stones" which are specifically needed. Protein metabolism has thus become essentially a question of the behavior of amino-acids in the body. As I have expressed it elsewhere:

> To-day we are concerned with the question whether this or that protein, whatever its biologic origin, will yield the characteristic desired, amino-acids, such as tyrosin and tryptophan, leucin and lysin, glycocoll and cystin, histidin and arginin. Our attention is fixed on the building-stones or units out of which the great protein structures are put together. Instead of referring to the proteins in terms of their physical properties or empirical composition—their content of carbon, hydrogen, oxygen, nitrogen or sulphur—at least so far as the problems of nutrition are involved, the time has arrived for estimating their behavior in the organism on the basis of the quota of each of about eighteen well-defined amino-acids which the individual representatives of this group of foodstuffs can yield. Most, if not all, of these amino-acids are essential for the construction of tissue and the regeneration of cellular losses. In proportion as any specific protein can furnish these constructive units it may satisfy the nutritive needs of the body. The efficiency of the individual protein in this respect must depend on the minimum of any indispensable amino-acid that it will yield; for it is now known that some of them cannot be synthesized anew by the animal organism. If, for example, a protein or mixture of proteins comparatively deficient in their yield of the sulphur-containing amino-acid cystin be furnished alone to supply the body's nitrogenous requirements, the production of new, cystin-yielding molecules of protein will be limited by the amount which is available in the diet. An excess need not be wasted, for it can be burned up like sugar or fat to provide energy; but new construction or growth is limited by the minimum of the essential unit.

The views just amplified have been substantiated by the more recent investigations in nutrition, particularly in the feeding of laboratory animals such as rats and mice. Thus, with an otherwise adequate diet the nitrogenous factors can be suitably supplied by proteins isolated from a considerable diversity of both animal and plant sources. The list includes such representatives as casein (milk), lactalbumin (milk), ovalbumin (hen's egg), ovovitellin (hen's egg), edestin (hemp-seed), globulin (squash-seed), excelsin (Brazil-nut), glutelin (maize), globulin (cotton-seed), glutenin (wheat), glycinin (soy-bean), cannabin (hemp-seed), as well as the total proteins present in various animal and plant tissues such as meat (muscle tissue), liver, kidney, brain, peanut, soy-bean, cotton-seed, etc. In contrast with the growth of white rats, for example, to adult size on mixtures of isolated food substances containing any one of the above as the chief source of protein in the diet is the failure to grow on foods containing other proteins which have a recognized deficiency in their amino-acid make-up, *i.e.*, "incomplete" proteins.

In every-day life neither man nor animals ordinarily eat a single type of protein or even proteins from a single source. The intake consists, rather, of a mixture of proteins rarely, if ever, including only such as are entirely deficient in their amino-acid make-up from the physiological standpoint just defined. Nevertheless there may be a *relative* deficiency of some essential nutrient unit or "building stone" in comparison with the amount of other essentials. Building progress—tissue construction—may then be retarded by the lack of proportionate quantities of all the needed parts that cannot be synthesized directly by the body.

An apparent exception to the demonstrated need of supplying all nitrogenous essentials more or less ready-made to the animal organism has been recorded in certain ruminants. Sheep have been observed to gain many pounds over considerable periods of time on a diet of starch, denitrogenized straw, inorganic salts and urea, an exceedingly simple nitrogenous compound that readily disintegrates to form ammonia and carbon dioxid. A consideration of the peculiar anatomical arrangement of the alimentary tract of these animals serves to explain the possibility of such an outcome. In the first stomach of the ruminants, the rumen or paunch, opportunity is afforded for micro-organisms to thrive in the warm reservoir where the food mixtures are temporarily incubated, so to speak. Bacteria can and do grow luxuriantly there. Subsequently when the products of microbial activity including an enormous increment of bacterial bodies are moved along to the true, acid-secreting stomach, the bacteria, rich in newly synthesized protein-containing protoplasm, die and liberate the bacterial protein for use by the organism of the host. This is a unique instance of apparent protein synthesis by a higher animal, explicable however on the basis of the symbiotic action of bacteria. The same result could not be expected in man, because his food passes directly into a chamber, the stomach, provided with bactericidal facilities in the acid gastric juice.

Even when the dietary food proteins are selected with a view to furnishing an adequate supply of all amino-acids known to be requisite, the nutritive processes of the body may exhibit defects not of supply but of utilization. A fire box may be equipped with a certain type of grate to burn coal of various sizes. If the grate is changed smaller sizes of fuel like pea coal may escape combustion by falling into the ashpit. So it happens that under as yet obscure conditions certain amino-acids fail to be completely

consumed or utilized in the metabolism. Consequently they are eliminated more or less unchanged with the waste products. Cystinuria and alkaptonuria represent illustrative instances.

There are other cases in which a presumably adequate intake fails to unfold its entire nutritive possibilities because some defect in the organism interferes with complete conversion of some ingredient. There are times when fats may fail of digestion and absorption. They then make their way through the entire length of the digestive tract, finding a way out with the stools. The disturbance or difficulty is one of digestion or alimentation. However, the fats may be digested, absorbed, and transported only to meet with inadequate chemical destruction in the usual reactions that liberate energy. Products of incomplete combustion arise, just as they do in the coal fire or gas engine. There may arise aceton, diacetic acid or betaoxybutyric acid, substances that are physiologically offensive and objectionable, that may induce an "acidosis," and that are speedily eliminated as well as possible.

Again, who is not familiar with the common condition known as diabetes in which sugar is not properly metabolized or stored in the body? There are in this country alone more than half a million diabetics, persons who fail to burn up one of the most common of food fuels. Striking statistics gathered by Doctor Joslin, of Boston, a conscientious student of diabetes, show an undeniable association of obesity and diabetes. It appears that persons above the age of fifty rarely acquire the disease, *i.e.*, the inability to burn certain kinds of food fuel well, if their weight is not above normal. Joslin writes:

> Diabetes is largely a penalty of obesity, and the greater the obesity, the more likely is Nature to enforce it. The sooner this is realized by physicians and the laity, the sooner will the advancing frequency of diabetes be checked. The penalty of taking too much alcohol is well known, and a drunkard is looked on with pity or contempt. Rarely persons who become fat deserve pity because of a real tendency to put on weight despite moderate eating, but usually most should be placed in somewhat the same category as the alcoholic. In the next generation one may be almost ashamed to have diabetes. It is all nonsense to use polite terms for being "just fat." It is generally prudent and always far more effective to say to the patient: "You are too fat," than cautiously to remark: "You are a trifle obese." Fat diathesis! Granted there is one person in a thousand who has some inherent peculiarity of the metabolism which has led to obesity, there are 999 for whom being fat implies too much food or too little exercise, or both combined.

Successful nutrition therefore not only demands the nutrient units properly digested and absorbed but also entails an organism in functioning condition to dispose of them. A water-power plant may become impaired not only when the supply reservoir runs low but also when its turbines or energy-converters are defective. But proteins and fats and sugars and their immediate chemical relatives are not the only indispensable factors in a successful diet. Present day physiology—again largely a product of the work of American investigators—has demonstrated the dominant importance of certain inorganic factors—of calcium phosphorus, chlorin, etc., and has given striking evidence of the rôle played by the so-called vitamines. The spark plug and lubricants help to make effective the energy stored in the gasoline supply of a heat engine. In nutrition likewise there are "accessories" without which the animal mechanism fails to run smoothly. The story of their importance may already be found portrayed with almost dramatic effect in the popular literature of the day.

It is instructive to follow the reaction of the public and the professions dealing with nutrition to each progressive step in the understanding of the nutritive functions. When the extent to which digestion occurs in the alimentary tract began to be disclosed by adequate experiments the predigestion of foods was promptly advocated, particularly for the sick and the young supposedly equipped with only feeble digestive apparatus. Meat and wheat and milk were prepared in a diversity of predigested forms by the physician, by the layman acting on his advice, and by the manufacturer.

To-day few remember the multiplicity of unpalatable products that were advertised and advocated a generation ago. In those days one might have spoken of foods "predigested to absorb" as nowadays one is reminded of foods "cooked ready to serve." No one seems to have asked whether the human alimentary tract was often so enfeebled as to require digestive help, or whether the exercise of the digestive function were not beneficial rather than baneful. Disuse of some organs leads to atrophy. An unexercised muscle becomes flabby. With the waning prominence of predigested foods, "isolated" foods, and notably protein food products waxed in popularity. The protein of pot cheese was sold at liberal profits, as a dietary supplement, mostly to the highly educated classes who are sometimes also highly credulous. At

present we are threatened with an avalanche of vitamine preparations. Somehow the drug store always manages to compete with the butcher shop and grocery, even in the domain of dietetics.

Students of nutrition are sometimes asked how it happens that nations have been so successfully nourished in the past despite the lack of knowledge of what are now regarded as fundamentals of nutrition. A partial answer has been formulated by Professor Hopkins:

> In many departments of human knowledge the teaching and guidance of science are accepted as final because in these departments the knowledge arose in the first instance from scientific studies and from these alone. Progress in such categories depends entirely upon controlled and recorded observation or upon experiment, and these are the methods of science. It is otherwise, one might be tempted to say, in regions where mankind can claim abundant and accumulated empirical experience. In connection with his own nutrition man's experience has been—needless to say—coterminous with his whole existence. Science may explain that experience, but is unlikely, it might seem, to improve upon experience as a guide. It may supply theory, but where experience has been so great and so continuous it seems unlikely that it could do much to guide practice. This consideration, consciously or subconsciously, accounts, I think, for a widespread feeling that the teachings of science about our food supply are of academic interest only.

We may hasten to add, however, that when peoples are forced to depart from the traditional practices that experience has shown to be safe, danger may arise. This is what happened in such unfortunate ways during the war. It is what may happen anywhere whenever persons depart from established and well tested customs to enter novel paths. Thus the substitution of polished rice for the unmilled variety led to nutritive disaster, often told in the story of beriberi. Pellagra has a related history. Rickets has a background of defective diet. Scurvy, too, attends the neglect of conventional modes of feeding. There is, then, room for a science of nutrition even in the domain of practical dietetics. Not all nations bungled their food problems during the war. How our British allies feel has lately been expressed by Professor Halliburton:

> Lord Rosebery, in a sentence that has stuck in our memories, said some years ago that "we generally muddle through somehow," but in connection with food there has been in this country a minimum of muddle, rationing has gone smoothly, there has been but little hardship, and we are through. How far physiology has been instrumental in helping to bring about this happy result I may safely leave to the judgment of others.

INTERNAL COMBUSTION ENGINES IN MARINE SERVICE.*

BY

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Member of the Institute

PART I.

PRESENT STANDARD OF MOTORSHIP AND TURBINE STEAMSHIP COMPARED.

AT no time in marine history has there been so great a variety of ship-propelling machinery as at present, and consequently never has it been so difficult to forecast the future, or to formulate a policy of construction. Without some generally accepted policy, the machinery builder hesitates to face the risks of heavy investments for development and production of any one type of equipment that may not be acceptable to shipping interests in the near future, and shipping interests are reluctant to adopt any one type that may soon become obsolete. At this time of greatest engineering evolution, the general stagnation of business has forced hundreds of ships out of service, and practically stopped all demand for new construction. This condition, while very serious in most ways, will probably in the end prove to be a good thing, as it not only gives an opportunity for study, discussion, and appraisal of the situation, but really compels such a procedure.

If proper use is made of the opportunity to analyze each of the new types of ship propulsion proposed, and to arrive at some conclusions that can be generally accepted at least as to the relative position and value of each type, then we may be able to evolve a sound program. Such a program will undoubtedly involve the re-powering of some existing idle ships where the machinery is found to be already obsolete, and thus will provide immediate work for maintaining our shipyards and machine shops, which can then continue with new construction on the same program. Unless something of this sort is done, it is difficult to see how American

* Presented at the Stated Meeting of the Institute held Wednesday, April 20, 1921.

ships can compete with foreign ones, and our hopes for a stabilized American merchant marine can hardly be realized.

Those nations that regard their merchant marine as essential to their existence, will be most certain to immediately adopt and put into service any new propulsion plan that promises economies of ship operation. Such action will force the ships of the others that lag behind, into a losing position by making their older types of machinery obsolete in comparison with the new type adopted by the leaders. This taking of leadership by earliest adoption of newer and more economical propulsion has its risks also, risks of impaired life, less reliability, greater repairs, doubtful manœuvering ability and such matters, but these are the ordinary risks of all development and progress, and are largely matters of engineering, which, if good, reduces such risks to a minimum.

The relative economy of operation of one type of machinery installation compared with another is a matter of comparative operating costs and earnings, and each of these is the aggregate of a large number of items, some of which have high and others low values, for every different class of equipment. They also vary with the prices of consumable materials, including fuel, with wage scales, with freight rates, and by no means least, the amount of use to which the plant is put, measured by its average yearly load compared with the installed capacity. To arrive at any proper appraisal of value for one type of equipment, these items must all be known separately and added together, or estimates sufficiently good for appraisal purposes may be based on general averages for groups of items, when there is enough experience to make the average worthy of respect.

A great many estimates of this sort have been made and practically every time a proposal is offered for new ship machinery, this operation is repeated with sometimes more and sometimes less care, or accuracy, and open-mindedness. Many papers on the subject have been published. As a result it is generally understood by those most concerned, that there is no one best machinery installation for ships for all sizes, speeds, routes, periods of time and prices of commodities, and there probably never will be. That which is best for one condition may well be worst for another. The situation here may well be summarized by saying that relative economy depends more or less equally on four classes of factors, any one of which may control. These factors are:

a. Use factor;
b. Price factor (consumable supplies and wages);
c. Performance factor;
d. Investment factor.

High use factors favor, or rather are necessary for heavy investment charges as controlling the yearly returns or income for a given investment. High price factors favor equipment working with low consumption of consumable supplies and low labor requirements for both operation and repair. High performance factors, representing large consumption of consumable supplies, mainly fuel, are always unfavorable, and are permissible only when other items are low because of it, as, for example, the investment factor. High investment factors representing large first costs are justifiable in proportion as other factors are so reduced by this high investment as to yield larger net percentage returns on high, than on low investments.

That analysis of operating economy will be most satisfactory which first eliminates all non-competitive equipment, and then for each of the remaining types of main power generating machinery, of auxiliary machinery and of propeller drives, determines the values of its performance and investment factors, and assigns to each one its own appropriate use factor limits, for fair ranges of the price factors. This analysis will have the effect of dividing all sea-borne traffic into classes or zones, according to the use factors representative of each in terms of length of voyage or of cargo ton-miles per year for example, in each one of which a given type of ship would be most economical with given prices, and which would change with prices. In proportion as the economic zones have the least overlap, so will the different kinds of ships be least competitive, and the proper place for each in world cargo-carrying be determined, as the basis of a program of construction and reconstruction.

This is not an easy task, and its complete and accurate execution may hardly be expected, but in proportion as it is approached and re-checked periodically, so will order and certainty emerge from disorder and uncertainty. Fair approximations for specified cases of comparison are not difficult and a start can be made this way. This is undertaken in what follows and it is hoped that some useful conclusions can be based on the method developed.

If there were no diversity of machinery, each with different

factors of investment and performance, the problem would be purely one of size of ship, price of fuel and other supplies, wages and number of crew, and this was the situation before the steam turbine and the internal combustion engine appeared. At that time the more expensive steamship had proved itself to be more economical than the cheaper sailing vessel, mainly through greater use factors and in spite of additional operating expenses for consumable supplies. Also at this time, all steamships were coal burners with reciprocating steam engines and differed in performance factors according to the efficiency of their reciprocating steam engines and auxiliaries, the one having higher efficiency always costing more to install and usually also to maintain. Here again, experience demonstrated that the higher investment costs for the more efficient coal-burning steamer were justified and profitable whenever the use factors were high, and not so when they were low, so the small tramp steamer of uncertain cargo-carrying capacity per year was properly propelled by the cheapest and least efficient machinery.

The old stable situation, where the problems were mainly non-engineering in character, and competition depended on crew wages and size with a given size of ship, on shipping management, and possibly on government coöperation, has for the moment entirely disappeared, and while some of the old problems remain, new ones have come forward and are to-day dominant.

These new ones are the result of, (*a*) the use of oil as fuel in competition with coal; (*b*) the steam turbine; and (*c*) the internal combustion engine. The first reduces fire-room crew, increases cargo capacity, decreases time, frequence and expense for loading fuel, and it has resulted in the establishment of fuel oil storage stations throughout the world, which have contributed to the introduction of the heavy oil internal combustion engine. Another effect of no small consequence has been the stimulation of new oil-well developments, in coöperation with the parallel demand of the automotive industries for greatly increased amounts of petroleum products, a true coöperation, because those parts of the crude oil that the latter cannot use as rejected residue, the former can use effectively.

One of the lessons taught by the substitution of fuel oil for coal in steamers, is that a higher specific price per million B.T.U. may be fully justified by reduced costs in other directions, and that the

more expensive fuel to buy, may be the cheapest to burn. This lesson is again repeated by the internal combustion engine in increasing degree, as is also the older lesson that increased investment costs may be more profitable than lesser ones.

The steam turbine, at first multi-staged to excess and direct coupled, was not very successful, many installations gave operating trouble and few showed a net saving in fuel, weight or cost. If it had not been for the inherent fundamental soundness of the turbine idea, inspiring persistent efforts to overcome mechanical troubles, and to reduce cost to realize these possibilities, it might well have been abandoned as an unlucky experiment. Faith in fundamental soundness of principle of the turbine kept it alive, and constant study of mechanical and operating faults resulted in their steady reduction or elimination, at first on land for central station electric generation service. However, for marine use there still remained the inherent high speed of turbine and low speed of propeller, which required more study of failures and development of corrections. As a result of all this the high speed marine steam turbine of to-day is a successful machine and has come into general use with single or double reduction gear drive of the propeller shaft. This equipment has a lower steam consumption and higher thermal efficiency than the reciprocating engine it has displaced, and it costs less to install, thus having more favorable use, performance, and investment factors.

In the meantime the Diesel oil engine was going through a more or less similar history. Its inherently higher thermal efficiency, two to three times that of the steam turbine plant, attracted to it the same sort of attention as did the turbine with its promise of low weight, cost and good steam consumption. Diesel engine development proceeded in spite of handicaps of very much higher first cost, greater weight and doubtful reliability at first, because of efficiency prospects. As was the case with the turbine, its success was first established on land, and also as with the turbine, the early marine installations, were mostly failures, but again as with the turbine, faith in the soundness of fundamental possibilities has served to overcome the discouragements, and to-day it may be said that mechanical defects have been remedied by good design and workmanship, so that reliability is established quite equal to that of the turbine installation. While there are still a great many more different models of marine Diesel engines than

of turbines, some as good as the best and others not, some new and others old, some American and others European, and an even greater variety of auxiliaries, it is safe to say that the standard motorship installation of the day is the four-cycle, multi-cylinder (six or more), single-acting, air-injection engine with crosshead, direct coupled in pairs to twin screw propeller shafts. The corresponding standard for auxiliaries is a combination of small Diesel electric generating sets, with all engine room and deck equipment electrically operated, and with air compressors and compressed air storage tanks for manœuvering. There are many such ships in operation and some have been in service long enough to justify their acceptance as standards, especially as so much new construction follows the same lines with only natural improvements in details.

The corresponding standard of the steam turbine class is the geared turbine with single propeller shaft, served by oil-fired Scotch boilers with superheaters and with steam auxiliaries, both engine room and deck.

These two modern standards of new type cargo ship machinery installation are in competition with each other, and can be taken as the basis of any study of the several diversity factors affecting economy estimates. Such a study must be directed first, toward the fixing of the economic zone of operation for each type in terms of the use factors with given prices of supplies. After this is done, the possible modifications of both turbine and motorship standards, can then be studied as to their effect on economy or economic operating zone.

Such studies will involve in the case of the turbine, the effect of changing the propeller connection from gear to electric transmission from the turbine, and of changing auxiliaries from steam to electric, the electricity being generated by small turbogenerator sets, by Diesel oil engine generating sets, or taken from the main generators. In the case of the Diesel oil engine, it will involve an estimate of the effect of changing the engine from four-cycle to two-cycle, from single to double acting, from air injection to solid injection, from Diesel method to others not Diesel, of better utilization of air charges in the cylinder with higher mean pressures, of different stroke-bore ratios and rotative speeds, of different numbers of cylinders per engine, of trunk piston against crosshead. As to propeller connection the study must include the

effect of single screw direct coupled against twin, of larger numbers of small cylinder high-speed main engines, geared to a single propeller shaft, or for electric drive, each engine driving electric generators and with the motor on the propeller shaft, eliminating the auxiliary generating engines, and also the manœuvering air compressor with its storage tanks.

By effect of each change is meant the change in weight and space involved in relation to cargo-capacity, in first cost or investment, in disbursements for fuel and other consumable supplies, in labor for operation and repairs, and other items, with estimates of relative life and reliability. In every case the other diversity factors must be brought in to fix the economic position.

The first detailed step in all this is to compare the standard geared turbine ship with the corresponding standard motorship. For this it is necessary to assume certain typical conditions and the first of these is size, power and speed of ship, and to define each equipment by a list of its principal items.

The ships assumed are taken as 10,000 tons dead-weight, speed 12 knots, 288 nautical miles per day, each equipped with 3500 S.H.P., and of equal propeller efficiency for the twin-screw motorship and the single screw turbine steamer, the justification for which has been much discussed and pretty well established. Such a ship would be about 425 feet long, 55 feet beam and draft of 27 feet loaded.

These two machinery installations include the items listed in Table I and Table II, from which it appears that the machinery of the turbine ship weighs 632 long tons, and that of the motorship 1020 tons, a difference in favor of the former 388 tons, of which difference 37 tons is due to the difference in shafting and propellers for twin as compared with single screw, and 5 tons to electric compared with steam deck gear, leaving 346 tons, due to the machinery proper. There are also some items of hull difference, but taking into consideration additional fresh water and fuel tank capacity to equalize the steaming radius of the steamer with that of the motorship, which latter can rely on its double bottom bunkers alone, these hull-weight differences can be regarded as equalized in any general comparison.

The tables also show that on the basis of costs, which are estimated at this time of unstable prices in a falling market at about 20 per cent. less than a year ago, and, therefore, somewhat doubt-

ful though relatively fair, that the Diesel machinery will cost $581,000, the turbine machinery $275,000, a difference of $306,000 against the motorship. Of the difference $14,000 is due to twin propellers and shaft over single, $40,000, to electric over steam auxiliaries, leaving $252,000 difference due to propelling machinery proper.

These two ships complete are estimated to cost $1,556,000 for the motorship, or $156 per D.W. ton, and $1,250,000 for the

TABLE I.

Equipment List for Installation of Geared Turbine, 185 lbs. Steam Pressure, 100° Superheat, 28.5" Vacuum, Single Screw, 3500 S. H. P. at 90 R.P.M.

Group	Equipment Item	Weight. Long ton	Cost. Dollars
A	One 3500 S. H. P. geared turbine, with oil system, cooler and lubricating pumps	88.00	$88,000
B	Three Scotch boilers, full, complete with superheaters and stack, fuel oil burner sets and transfer pump, boiler feed pumps and feed water heater	320.00	80,000
C	Fresh water systems, tank, evaporator and distiller	6.00	1,500
D	Engine room power auxiliaries; main and auxiliary condenser, with circulating air and vacuum pumps	30.00	24,000
E	Engine room ship auxiliaries; ballast, sanitary, bilge and fire pumps	5.00	2,000
F	Two steam auxiliary generating sets 15 K. W. each with generators and switch boards	5.00	3,600
G	Fixed engine and boiler room equipment; piping, platforms, spares and stores	35.00	32,000
H	Deck auxiliaries; ten steam winches, windlass and steering engine	55.00	20,000
I	Power transmission; propeller, shafting and bearing and stern tube	88.00	24,000
	Total	632.00	$275,000
	Total per S. H. P.	.180 tons	$79.00

geared turbine steamer or $125 per D.W. ton, the difference of $306,000, or $31 per D. W. ton being against the motorship.

The cargo capacities of these ships will not be equal because of the differences in machinery weights and in consumable supplies such as stores, water and fuel oil, mainly the latter. To estimate these items it is necessary to establish consumption rates per day at sea and in port, and to apply these to different lengths of voyages and port periods over a year to get yearly cargo-capacity, assuming the ship to be full every voyage, from which by applying freight rates the yearly gross earnings of the ship can be estimated.

Both ships will burn the same fuel oil and as a fair average of the world's supply, bunker oil of 14°–16° Baume will be taken. It has been the custom to operate Diesel engines on a higher grade oil of suitable viscosity to be handled cold by the engine metering pumps, to give a properly fine spray when injected. Recent tests of oil conditioning equipment have proved that the viscosity

TABLE II.

Equipment List for Twin Screw Diesel Engine (65 B. M. E. P.), 3500 S. H. P., 120 R.P.M. Installation.

Group	Equipment Item	Weight. Long ton	Cost. Dollars
A	Two 1750 B. H. P., six cylinder air injection Diesel engines with attached air compressors, thrust shaft and bearing, exhaust manifold silencer, spray air bottles, lubricating oil filters, coolers, platforms and spare parts per Lloyds	700.00	$390,000
B	Three 150 B. H. P.-100 K. W. auxiliary Diesel engine generating sets with air bottles, silencers, piping valves 220 volts D. C. generator and controls	66.00	48,000
C	One small emergency oil engine lighting set, 10 K. W.	1.00	1,000
D	One donkey boiler, 200 square feet, with feed pump and oil burner, for heating ship and fuel oil	8.00	1,000
E	One motor drive three stage auxiliary air compressor, 220 H. P.	10.00	15,000
F	Pumps for fresh water, fire and bilge, ballast, fuel oil transfer, lubricating oil, bilge, fire and bilge, fresh water and sanitary and steam emergency air compressor	20.00	15,000
G	Fixed engine room equipment; additional piping, stack and tanks	30.00	13,000
H	Deck auxiliaries; ten electric winches, windlass and stearing gears	60.00	60,000
I	Power transmission; propellers, shafts, bearings and stern tubes	125.00	38,000
	Total	1020.00	$581,000
	Total per H. P.	.290 tons	$165.00

of oils that cannot be used cold can be changed by heating to the same values as the old standard Diesel fuel oils, and it is no longer necessary to select an oil for these engines when this fuel oil conditioning equipment is installed. This confirms the experience of the Navy as to equalization of oils by heating to equal viscosity when used in mechanical spray burners for steam boilers. This apparatus involves a steam heating system served by the donkey boiler and a centrifugal separator to remove all solids and water

after viscosity adjustment by heating, and which centrifuge by the use of a reagent can also break down emulsions into clean oil and water.

This fuel oil will weigh 8 lbs. per gallon, 338 lbs. per 42 net gal. barrels, or 6.62 bbls. per long ton, approximately.

The fuel oil consumption of Diesel engines is very constant and differs but little in service from test floor values, any mal-adjustment producing smoke immediately calls attention to a faulty spray valve which is easily corrected. The value may be taken as .46 lb. per S.H.P. hr. for all purposes at sea, which is about 10 per cent. above test value. This is equivalent to $3500 \times .46 = 1620$ lbs. per hour, 38,940 lbs. per day of 24 hours, 17.4 long tons; or 115 bbls.

In port the fuel consumption is much less, part being that for winch operation when handling cargo, and the rest that for pumps at all times, and ship lighting, both loads being carried by the auxiliary Diesel generating sets. For this service at variable load, the consumption is estimated at .6 ton per day for the twenty days in each port call. This makes the port consumption $20 \times .6 = 12$ tons, or 79 bbls. per port call.

The steam turbine ship fuel consumption at sea is based on the assumption that the turbine will have a sea water rate of 12 lbs. per S.H.P. on the average, about 20 per cent. above the test value, 2 lbs. per S.H.P. hr. for auxiliaries, making a total of 14 lbs. steam per hr. per S.H.P. for all purposes at sea, and 49,000 lbs. per hour total. The boiler evaporation is taken as 12 lbs. per lb. of oil, making allowance for normally imperfect adjustment of burners and air supply. This makes the fuel consumption for all purposes at sea, $\frac{49,000}{12} = 4092$ bbls. per hr. = 1.17 lbs. per hr. per S.H.P., which is equivalent to 98,208 lbs. per day of 24 hours, 44 long tons, or 293 lbs.

In port the steamer fuel consumption is estimated from ships in service as 30 bbls. per day for 20 days, or a total of 600 bbls., or 90 tons per port call, neglecting increases for winter steam heat, which will double the amount.

Comparing these consumptions the ratio of steamer fuel oil consumption to the motorship is, at sea, 2.5 times, and 7.5 times in port.

Fresh water estimates are based on 20 gallons per day per

man, or 3 tons per day for each ship for washing, drinking and cooking. Steamship make-up water is estimated at 1.5 per cent. of the boiler evaporation, or 10 tons per day at sea, to be stored in tanks, with an alternative of a lesser amount carried in tanks, and an increased fuel consumption to make fresh water by evaporation and distillation. It will be assumed that water can be obtained at any port and a one-way supply carried.

Stores for deck, engine and steward's department are estimated at one ton per day for each ship and as not always obtainable at every port, a round trip supply to be carried on leaving.

The aggregate weights of fuel, water and stores for a given voyage will depend on its length and so, therefore, will the cargo capacity, making allowance for machinery weight excesses.

No general conclusions as to relative economic scope of the

TABLE III.

Consumption Rates of Consumable Supplies (Long Tons).

Item	Per day at sea		Per day in port	
	Steamship	Motorship	Steamship	Motorship
Stores.....	1.00	1.00	1.00	1.00
Water.....	13.00	3.00	3.00	3.00
Fuel	44.00	17.40	90 tons per call—12 tons per call	

two typical ships can be based on a voyage length assumed, because the motorship is favored by long, and the steamer by short voyages, so that the problem becomes one of finding the voyage length that divides the economic zone of one ship from that of the other, and on a yearly basis of operating 350 days per year, allowing 15 days per year for docking and general overhaul.

For the purpose of such general comparison of types, it is necessary to reduce the number of variables to a minimum, and for graphical plotting to select a prime variable. This prime variable is here taken as the length of a single voyage in days, and in all cases the port stay is assumed to be the economical low limit of 20 days, which may possibly be too low, requiring as it does the handling of something less than 100 tons of cargo per day per winch, by whatever proportionate amount the total cargo is less than 10,000 tons in weight.

The calculation of consumable supplies is based on the rates

of Tables III, and the figures are tabulated in Table IV, for a complete round trip voyage. In this table the maximum length of voyage has been based on the double bottom bunker capacity of 1200 tons and the consumption of the motorship, and fixed at about 60 days, which the motorship can complete one way, without refuelling, and with about 10 per cent. reserve, filling bunkers at each end. To meet these conditions of voyage length, the steamer must have deep tanks of about 1700 tons additional fuel capacity. For voyages of half this length, or 30 days, both

TABLE IV.

Consumable Supplies: Tons per Return Voyage.

Days, Single Voyage		Stores		Water		Fuel		Total		Total Weight, 10% Reserve	
Sea	Lay	Out	In	Out	In	Out	In	Out	In	Out	In
STEAMSHIP											
5	20	50	25	125	125	310	310	485	460	531	506
10	20	60	30	190	190	530	530	780	750	855	825
20	20	80	40	320	320	970	970	1370	1330	1503	1463
30	20	100	50	450	450	1410	1410	1960	1910	2151	2101
40	20	120	60	580	580	1850	1850	2550	2490	2799	2739
50	20	140	70	710	710	2240	2240	3140	3070	3447	3377
60	20	160	80	840	840	2730	2730	3730	3650	4095	4015
MOTORSHIP											
5	20	50	25	75	75	99	99	224	199	244	219
10	20	60	30	90	90	186	186	336	306	367	337
20	20	80	40	120	120	360	360	560	520	612	572
30	20	100	50	150	150	534	534	784	734	857	807
40	20	120	60	180	180	708	708	1008	948	1103	1043
50	20	140	70	210	210	882	882	1232	1162	1348	1278
60	20	160	80	240	240	1056	1056	1450	1376	1594	1514

ships might carry oil for a return voyage, but the conditions are normally more favorable when the fuel is carried one way only, permitting an increase of cargo-capacity outbound equal to the fuel consumption one way. This is a matter of balancing relative values of this weight of fuel and of cargo.

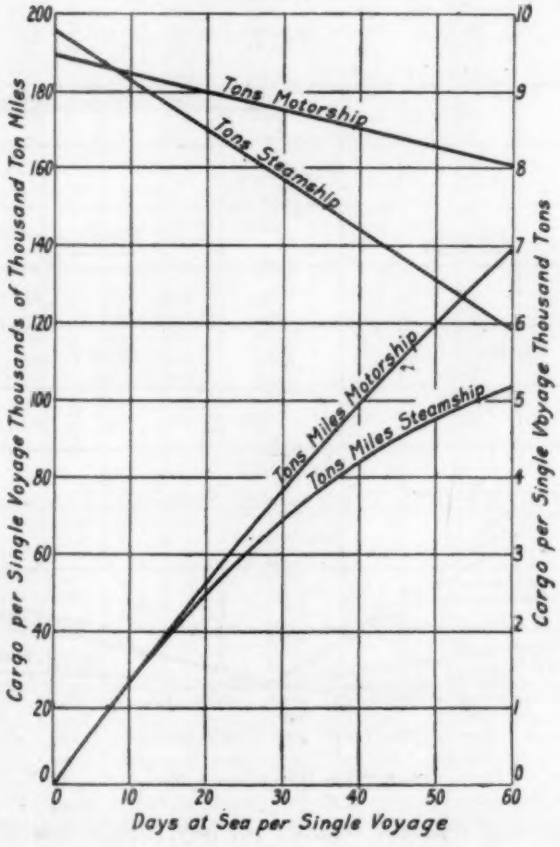
The cargo capacity determined by subtracting supplies from dead-weight is plotted in Fig. 1.

It will be noted that the steamship and motorship curves are not parallel but depart more widely as voyage length is greater, and in favor of the motorship.

To make this still more clear, the dead-weight distribution given in Table V is plotted in Fig. 2, making an allowance of 388 tons excess machinery weight of the motorship over the steamer.

Combining the items of cargo-capacity per single voyage with

FIG. 1.



Cargo-Capacity per Single Voyage Tons and Ton-Miles.

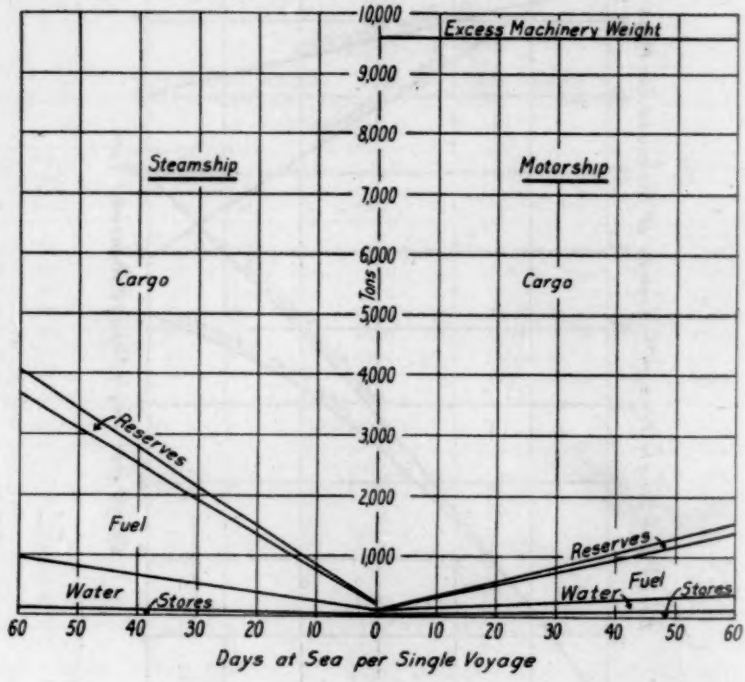
miles per voyage, voyages per year, and freight rates, the yearly gross earnings are found as reported in Table VI, for freight rates of $1, $2, and $3 per 1000 ton-miles. The corresponding returns for any other freight rate can be obtained by scaling.

This table of gross freight earnings brings out the interesting

fact that there is a maximum for each type of ship, for the steamer at less than 40 days length of voyage, and for the motorship at over 60 days length. The curves of gross earnings in Fig. 3 show this more clearly.

Mainly because of fuel economy, but also because of no fresh water make-up storage, the motorship freight earnings are con-

FIG. 2.



Dead-Weight Distribution in Tons.

sistently greater than the steamer for any freight rate, the actual difference being greater for longer voyages at any one freight rate and, of course, doubly so at the higher freight rates.

Disbursements per year for ship operation include two sets of items, one that is actually or practically independent of length of voyage, port stay or horsepower hours of power generated per year, and the other that varies with the factors entering into the latter item. These disbursements must be estimated and the total

TABLE V.

Dead-Weight Distribution (Long Tons) (Average Single Voyage)

STEAMSHIP

Sea days	Stores	Water	Stores Water	Fuel	Stores Water Fuel	Total + Reserve	Cargo 10,000 − (total + reserve)
5	38	125	163	310	473	520	9480
10	45	190	235	530	765	842	9158
20	60	320	380	970	1350	1485	8515
30	75	450	525	1410	1935	2129	7871
40	90	580	670	1850	2520	2770	7230
50	105	710	815	2290	3105	3416	6584
60	120	840	960	2730	3690	4059	5941

MOTORSHIP

Sea days	Stores	Water	Stores Water	Fuel	Stores Water Fuel	Total + Reserve	Cargo 9612 − (total + reserve)
5	38	75	113	99	212	233	9379
10	45	90	135	186	311	342	9270
20	60	120	180	360	540	594	9018
30	75	150	225	534	759	835	8777
40	90	180	270	708	978	1076	8536
50	105	210	315	882	1197	1317	8295
60	120	240	360	1056	1416	1557	8055

TABLE VI.

Cargo (D. W.) Capacity and Yearly Gross Freight Earnings.

STEAMSHIP

Days per single voyage		D. W. per single voyage ave.		Distance, miles	Ton-miles cargo per single voyage	Single voyage per year of 350 days	Thousand ton-miles per year	Gross earnings at freight rates per 1000 ton-miles of		
Sea	Lay	Supply	Cargo					$1.00	$2.00	$3.00
5	20	520	9480	1,440	13,650	14.00	191,000	$191,000	$383,000	$573,000
10	20	842	9158	2,880	26,390	11.65	307,200	307,200	614,400	921,500
20	20	1485	8515	5,760	49,050	8.75	429,500	429,500	859,000	1,266,500
30	20	2129	7871	8,640	68,000	7.00	475,500	475,500	951,000	1,426,500
40	20	2770	7230	11,520	83,300	5.84	485,500	485,500	971,000	1,456,500
50	20	3416	6584	14,400	94,800	5.00	474,000	474,000	948,000	1,422,000
60	20	4050	5941	17,280	102,600	4.38	449,000	449,000	898,000	1,347,000

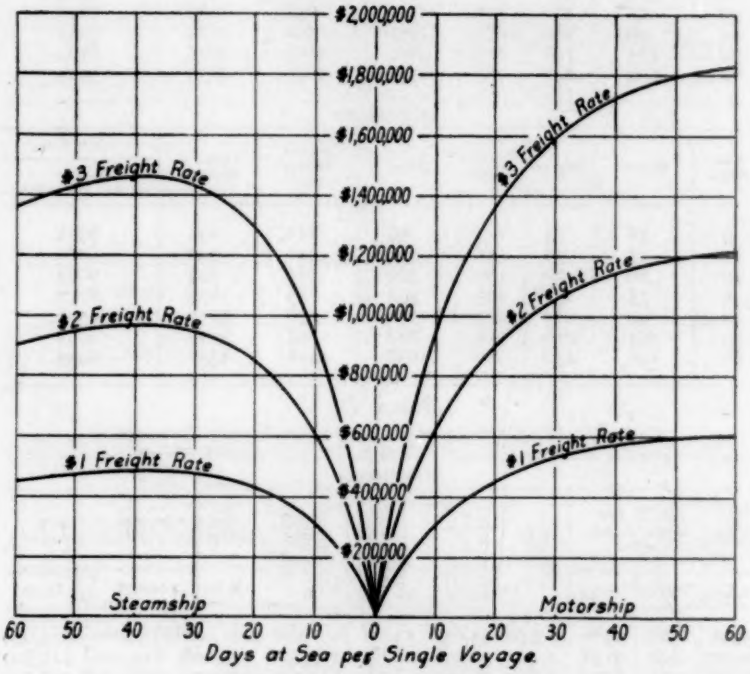
MOTORSHIP

5	20	233	9379	1,440	13,500	14.00	189,000	$189,000	$398,000	$567,000
10	20	342	9270	2,880	26,700	11.65	311,000	311,000	622,000	933,000
20	20	594	9018	5,760	52,000	8.75	455,000	455,000	910,000	1,365,000
30	20	835	8777	8,640	75,800	7.00	530,000	530,000	1,060,000	1,690,000
40	20	1076	8536	11,520	98,400	5.84	574,000	574,000	1,148,000	1,722,000
50	20	1317	8295	14,400	119,300	5.00	596,500	596,500	1,193,000	1,789,500
60	20	1557	8055	17,280	139,100	4.38	609,500	609,500	1,219,000	1,828,500

subtracted from the gross freight earnings to get yearly returns on the capital invested.

The returns so found may be distributed into various sinking fund reserve accounts, such as interest, depreciation, obsolescence, bond retirement, or part may be actually disbursed as profits or dividends. To establish the relative economic zones for the

FIG. 3.



Gross Freight Earnings per Year in Dollars.

two types of ships, this distribution of yearly capital returns need not be made, it is quite sufficient to determine the amounts, and this can be done without obscuring the issue with theories of accounting.

It has already been shown that there is a difference in gross freight returns for the two types of ships, and the same will be true as to disbursements for operating expenses, but in a somewhat different way. When the curves for these latter items are devel-

oped and compared with the former, the profitable zone of each type of vessel will be apparent.

Operating expense disbursements include items for maintenance, crew wages and subsistence, loss and damage, stores and insurance, as annual items, actually or substantially independent of the length of voyage. Port expenses and fuel are the only items large enough and sufficiently variable with the service or the power generated, to warrant independent calculation in terms of length of voyage. Cargo handling is omitted as it is more of a terminal or freight transfer charge than one of ocean transportation.

Maintenance data available, while not yet conclusive, do nevertheless point to substantial equality between the geared turbine machinery and the Diesel engine, each of good design. In the former case, the major single item is for the boilers. At prewar wages, labor efficiency and prices of material, the amount was about $8000 per year, and a year ago about twice this, $15,000 per year. Adding to this an amount for maintenance of ship, ship fittings and deck gear, and two dry dockings at $5000 each, the total would have been about $40,000 per year, or $4 per D.W.T. per year. At the present time with wages and prices falling, an estimate for the future must be somewhat of a guess, but a reduction of 20 per cent. will be made as was done for ship's costs. This makes the total $32,000 per year for each ship.

Crew wages and subsistence have been very carefully determined for conditions of the near past on established complements, and pay scales, and these figures will be reduced by 10 per cent. for wages, and 20 per cent. for subsistence in anticipation of a reduction likely to come soon, in line with all prices and wages. While it is possible to operate the motorship with less men than the steamer, no advantage is taken of this and both ships are charged with the same expense. To save space, the details of the crews will be omitted, but the summary is as follows: The engine room force consists of 17 men, receiving $24,400 per year for wages, and costing $7500 for subsistence, a total of $31,900 per year. Deck and stewards complements add 26 men to each ship with $30,000 wages and $11,400 subsistence or $41,400 together. This makes the total $73,300 per year for wages and subsistence for each ship.

Loss and damage is almost a pure guess, and for it a total of $10 per day for each ship is assumed, or $3650 per year.

Stores, exclusive of subsistence, and amounting to one ton per day, are priced at $60 per ton average, making the yearly charge $21,900.

Water is worth so small a sum per ton and the total yearly amount is also so small as to make this item of expense negligible, and it is, therefore, omitted.

Insurance is taken at the flat rate of 5 per cent. on the ship

TABLE VII.

Fixed Annual Disbursements.

Item	Steamship	Motorship
Maintenance	$32,000	$32,000
Crew wage and subsistence	73,300	73,300
Loss and damage	3,650	3,650
Stores	21,900	21,900
Insurance.....	62,500	77,800
Total.....	$193,350	$208,650

YEARLY PORT CHARGES, BOTH SHIPS

Day per single voyage	Single voyages per year port calls	Yearly port charges, approximate
5	14.00	$112,000
10	11.65	93,200
20	8.75	70,000
30	7.00	56,000
40	5.84	46,720
50	5.00	40,000
60	4.38	33,040

cost because this seems to be the custom, and in spite of the fact that it seems to be a high figure. This is equivalent to an annual charge of $77,800 per year against the motorship and $62,500 per year for the steamship.

These annual items together make up the totals for the fixed annual disbursements of the two ships as in Table VII.

To these totals are to be added amounts for port expenses, which vary with the days in port, and for fuel expense, which varies with days at sea and in port.

TABLE VIII.

Annual Fuel Expense.

Days per single voyage	Single voyages per year	Fuel tons per single voyage	Fuel tons per year	Fuel bbls. per year	Fuel expense per year at dollars per bbl. of				
					1	2	3	4	5
STEAMSHIP									
5	14.00	310	4,340	28,730	$28,700	$ 57,500	$ 86,200	$114,900	$143,700
10	11.65	530	6,175	40,875	40,900	81,750	123,000	163,500	204,400
20	8.75	970	8,488	56,185	56,200	112,400	168,600	224,700	280,900
30	7.00	1410	9,870	65,340	65,300	130,700	196,000	261,400	326,700
40	5.84	1850	10,800	71,520	71,500	143,000	214,600	286,100	357,600
50	5.00	2290	11,450	75,800	75,800	151,600	227,400	303,200	379,000
60	4.38	2730	11,957	79,160	79,200	158,300	237,500	316,600	395,800
MOTORSHIP									
5	14.00	99	1386	9,175	$ 9,200	$18,350	$27,500	$36,700	$ 45,900
10	11.65	186	2167	14,345	14,300	28,700	43,000	57,400	71,700
20	8.75	360	3150	20,853	20,850	41,700	62,600	83,400	104,300
30	7.00	534	3738	24,746	24,700	49,500	74,200	99,000	123,700
40	5.84	708	4135	27,374	27,400	54,700	82,100	109,500	136,900
50	5.00	882	4410	29,194	29,200	58,400	87,600	116,800	146,000
60	4.38	1056	4625	30,618	30,600	61,200	91,900	122,500	153,100

TABLE IX.

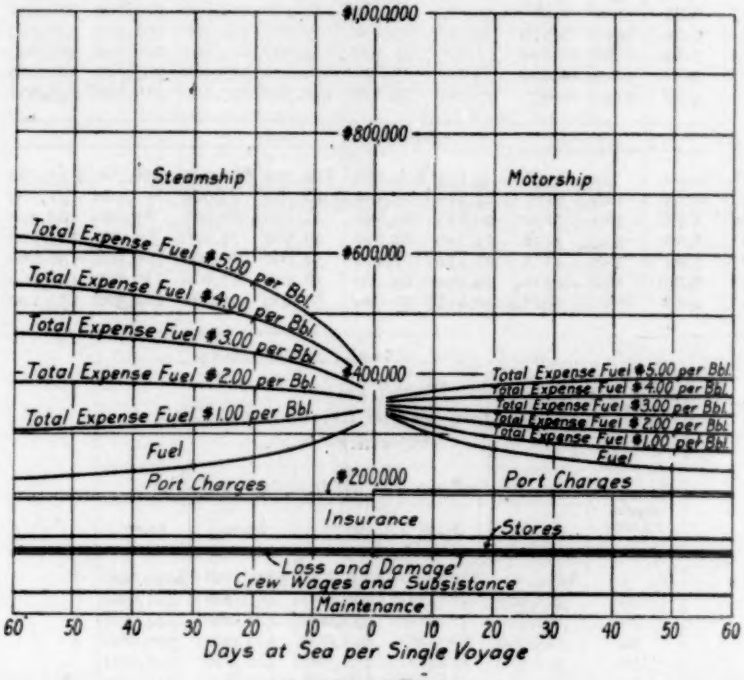
Total Annual Expense.

Days per single voyage	Total expense with fuel in dollars per bbl. at				
	$1.00	$2.00	$3.00	$4.00	$5.00
STEAMSHIP					
5	$334,000	$363,000	$391,500	$420,000	$449,000
10	327,500	368,000	409,000	450,000	491,000
20	319,500	376,000	432,000	488,000	544,000
30	315,000	380,000	445,000	511,000	576,000
40	311,500	383,000	454,500	526,000	598,000
50	309,000	385,000	461,000	536,000	612,000
60	307,000	387,000	466,000	545,000	624,000
MOTORSHIP					
5	$329,500	$339,000	$348,000	$357,500	$366,500
10	316,500	330,500	344,500	359,000	373,500
20	299,500	320,500	341,500	362,000	382,500
30	289,500	314,000	338,500	363,500	388,500
40	282,500	310,000	337,500	364,500	392,000
50	277,500	307,000	336,000	365,500	394,500
60	274,500	304,500	335,500	366,000	396,500

Port charges, exclusive of cargo handling, represent the cost of entering, leaving, and remaining in port in proper position to handle cargo, and this expense will be the same for both ships, so detailed itemization is not worth while. A round figure of $400 per day in port will be assumed, and as the stay in port is fixed at 20 days, this means a charge of $8000 per port call. The yearly port charge totals are given in Table VII.

Fuel expense can be determined from the consumption figures

FIG. 4.



Total Annual Expense.

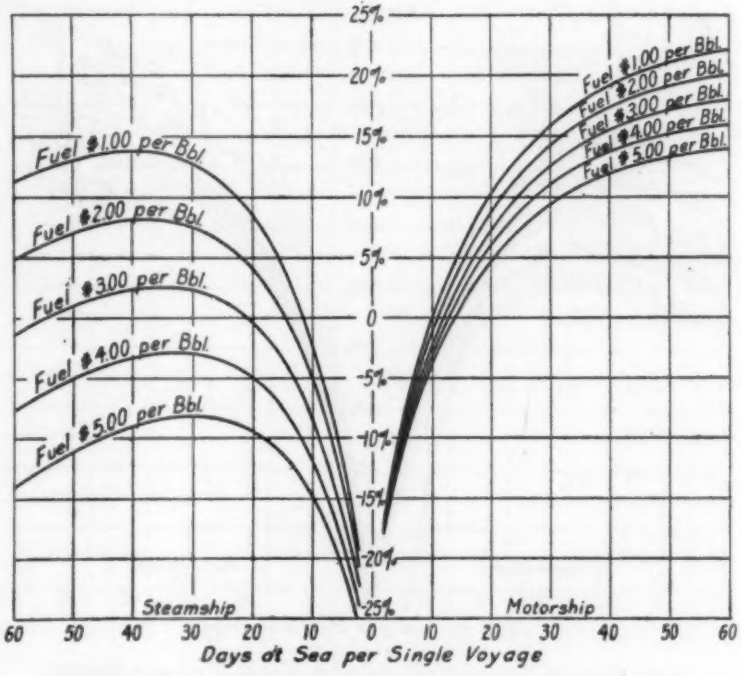
and days at sea or in port by applying a price. As price is a variable in the fixing of economic zones, no one value will be taken, but the total computed for a range from $1 to $5 per bbl. within which fuel oil prices for bunker grades will surely lie for a long time to come. This fuel expense calculation is assembled in Table VIII.

To the fuel expense per year, which increases regularly, with length of voyage, there is to be added the port expense per year, which decreases with length of voyage, the sum for low fuel prices

decreasing with length of voyage, becoming about constant for moderate fuel prices, and increasing with high fuel prices. The fixed annual expenses added to the above sum, give total yearly expense, per Table IX, and as plotted in the curves of Fig. 4.

These curves show clearly that exclusive of fuel, the yearly expense is slightly greater for the motorship, but including fuel, the situation is reversed, the total being always greater for the

FIG. 5.



Annual Return on Investment with Freight Rate at $1.00 per 1000 Ton-Miles.

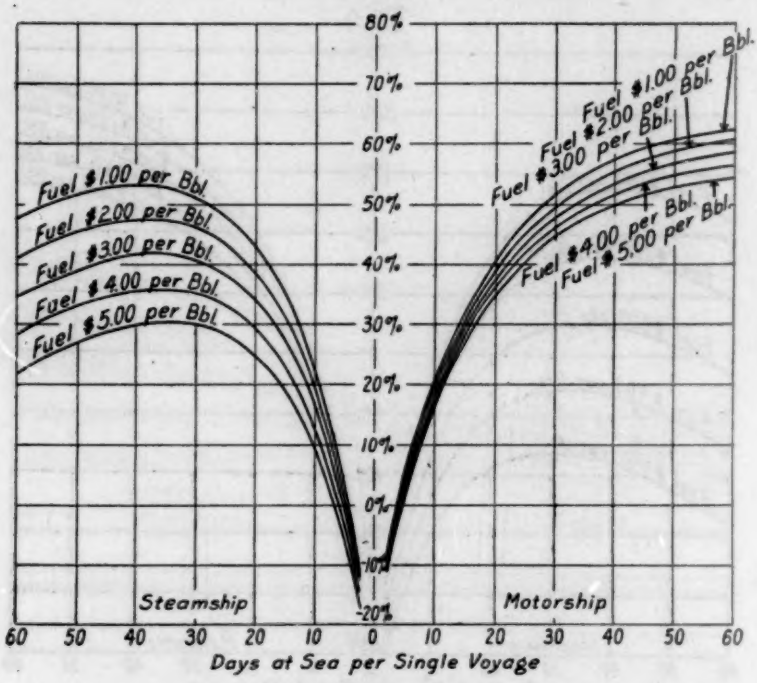
steamer for any voyage length, and the excess itself being greater as fuel prices rise.

Subtracting the annual expense of Table IX and Fig. 4, from the annual freight income of Table VI and Fig. 3, there is found the annual returns on the investment in dollars per year, and per cent. on the first cost of the ship per Table X, *A* for $1, *B* for $2 and *C* for $3 freight rates per 1000 ton-miles, each for fuel oil prices from $1 to $5 per bbl. These per cent. returns on the

investment are plotted in three curves, Figs. 5, 6 and 7, for the three freight rates.

It will be noted from the curves that in all cases the returns for the steamship reach a maximum and then fall, as length of voyage increases, while for the motorship no maximum is reached. The curves for the two ships are at first, *i.e.*, for short voyages,

FIG. 6.



Annual Return on Investment with Freight Rate of $2.00 per 1000 Ton-Miles.

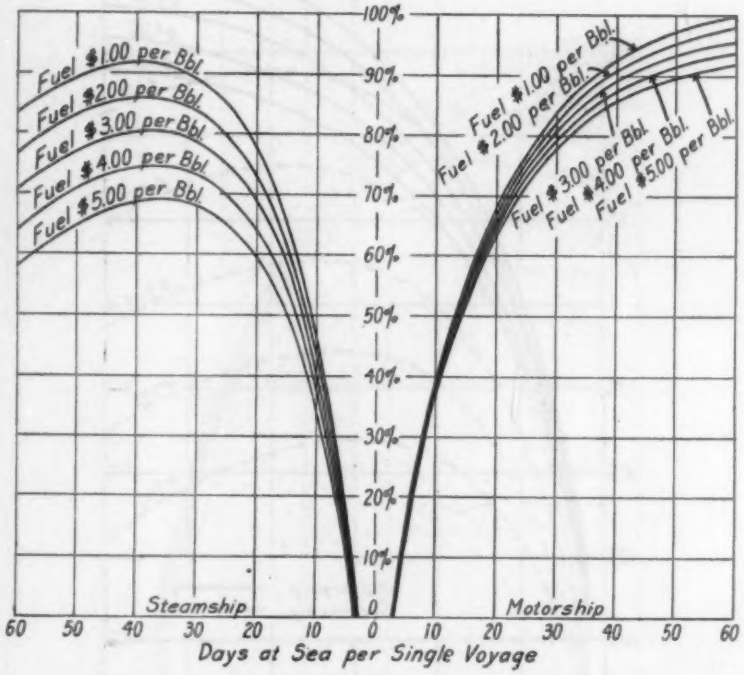
nearly straight lines and more or less parallel, a condition that indicates a competitive condition for short voyages. As voyage length increases, however, the curves of steamship returns flatten out, while those of the motorship continue to rise, indicating a non-competitive condition, or one of definitely clear superiority of the motorship. Just where the competitive condition ends, or for what lengths of voyage the two ships yield substantially equal returns, or below what voyage length the steamer is more profit-

able, or above which the motorship returns are better, depends on freight rates and on fuel oil prices.

That there are clearly independent as well as clearly competitive zones becomes more clear as these investment returns are compared directly, as is done in Table XI, and curves of Figs. 8, 9 and 10, for $1, $2 and $3 freight rates, respectively.

Before analyzing these zones of superiority of one ship over

FIG. 7.



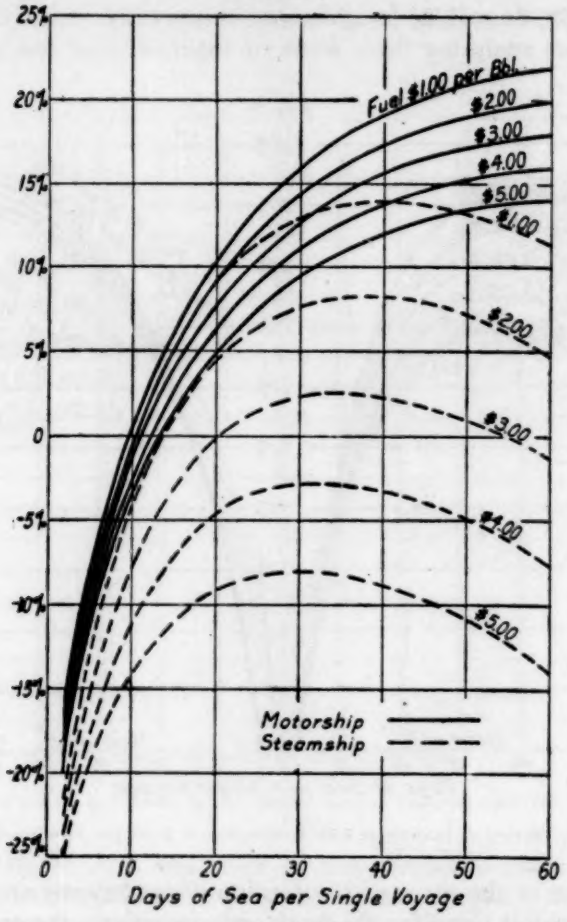
Annual Return on Investment with Freight Rate of $3.00 per 1000 Ton-Miles.

the other, or the zones of competition where returns are substantially equal, it simplifies the work and strengthens the conclusions to examine into the relative importance of one freight rate, or one fuel price over the rest, and incidentally also to note that all results are based on the assumption of 20 days' stay in port.

With regard to port stay, it is clear that any other port stay that produces the same per cent. time in port or at sea, or the same

number of sea and port days per year, means the same thing. All the figures applying to the 20-day port stay with 10 days at sea, also apply to 30 days in port and 15 days at sea, and to

FIG. 8.



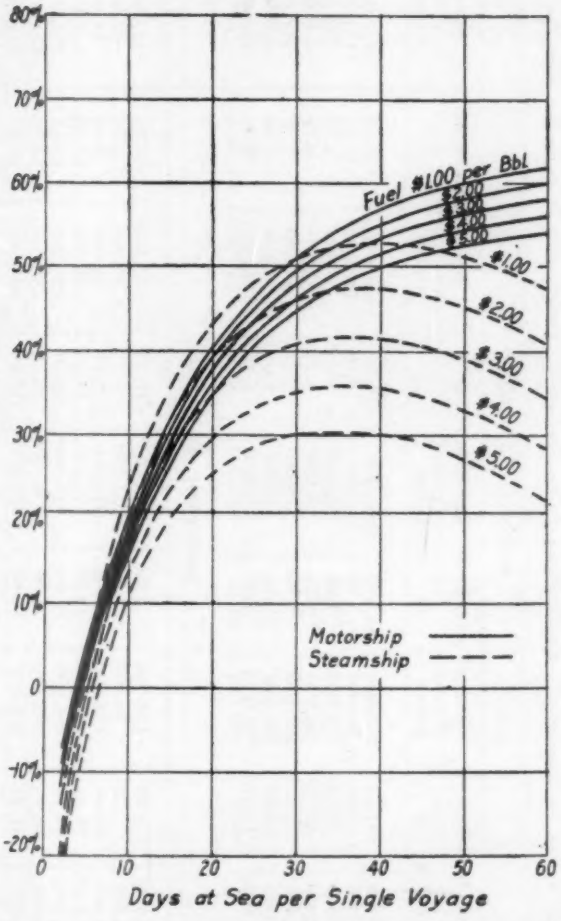
Annual Return on Investment with Freight Rate of $1.00 per 1000 Ton-Miles.

40 days in port with 20 days at sea. This extends all conclusions to any length of port days by selecting the appropriate number of sea days.

Freight rates per 1000 ton-miles are most variable items, fol-

lowing no fixed general rule and constantly fluctuating, but this is a matter of little consequence in comparing the profitable zones of two different ships so long as any fair or typical rate is selected to

FIG. 9.



Annual Return on Investment with Freight Rate of $2.00 per 1000 Ton-Miles.

be applied to both. To arrive at such a rate, the quotations of the current month have been taken for heavy cargo of limited length, such as machinery, for example, and these rates are compared

TABLE X (A).

Annual Return on Investment. Undistributed Excess or Deficit. Freight Rate of $1.00 per 1000 Ton-Miles.

Days per single voyage	Fuel at $1 per bbl.		Fuel at $2 per bbl.		Fuel at $3 per bbl.		Fuel at $4 per bbl.		Fuel at $5 per bbl.	
	Dollars	%	Dollars	%	Dollars	%	Dollars	%	Dollars	%
STEAMSHIP, $1,250,000										
5	-143,000	-11.44	-172,000	-13.76	-200,500	-16.00	-229,000	-18.32	-258.000	-20.64
10	- 20,000	-1.60	- 61,000	- 4.88	-102,000	- 8.16	-147,000	-11.76	-184,000	-14.72
20	110,000	8.80	53,500	4.28	- 2,500	- .20	- 58 500	- 4.68	-114,500	- 9.16
30	160,500	12.84	95,500	7.64	30,500	2.44	- 35,500	- 2.84	-100,500	- 8 04
40	174,000	13.92	102,500	8.20	31,000	2.48	- 40,500	- 3.24	-112,500	- 9.00
50	165,000	13.20	89,000	7.12	13,000	1.04	- 52,500	- 5.00	-138,000	-11.04
60	141,500	11.32	62,000	4.96	- 17,000	- 1.36	- 96,000	- 7.68	-175,000	-14.00
MOTORSHIP, $1,550,000										
5	-140,500	- 9.04	-150,000	- 9.64	-159,000	-10.23	-168,500	-10.83	-177,500	-11 40
10	- 5,500	- .35	- 19,500	- 2.50	- 33,500	- 2.15	- 48,000	- 3.09	-62,500	- 4.02
20	155,500	10.00	134,500	8.64	113,500	7.28	93,000	6.04	71,500	4.59
30	240,500	15.45	216,000	13.88	191,500	12.30	166,500	10.70	141,500	9.10
40	291,500	18.75	265,000	17.00	236,500	15.20	209,500	13.45	182,000	11.70
50	319,000	20.50	289,500	18.60	260,500	16.75	231,000	14.85	202,000	13.00
60	335,000	21.50	305,000	19.60	274,000	17.60	243,500	15.65	213,000	13.70

TABLE X (B).

Annual Return on Investment. Undistributed Excess or Deficit. Freight Rate of $2.00 per 1000 Ton-miles.

Days per single voyage	Excess income over disbursements or deficit									
	Fuel at $1 per bbl.		Fuel at $2 per bbl.		Fuel at $3 per bbl.		Fuel at $4 per bbl.		Fuel at $5 per bbl.	
	Dollars	%	Dollars	%	Dollars	%	Dollars	%	Dollars	%
STEAMSHIP, $1,250,000										
5	49,000	3.92	20,000	1.60	−8,500	−.68	−37,000	−2.96	−66,000	−5.28
10	287,000	22.96	246,500	19.72	205,500	16.44	164,500	13.16	123,500	9.88
20	539,500	43.16	483,000	38.64	427,000	34.16	371,000	29.68	315,000	25.20
30	636,000	50.88	571,000	45.68	506,000	40.48	440,000	35.20	375,000	30.00
40	659,500	52.74	588,000	47.04	516,500	41.32	445,000	35.60	373,000	29.84
50	639,000	51.12	563,000	45.04	487,000	38.96	411,500	32.92	336,000	26.88
60	590,000	47.24	511,000	40.88	432,000	34.56	353,000	28.24	274,000	21.92
MOTORSHIP, $1,556,000										
5	68,500	4.40	59,000	3.79	50,000	3.21	40,500	2.60	31,500	2.02
10	305,500	19.62	289,500	18.60	277,500	17.83	263,000	16.90	248,500	15.95
20	610,500	39.20	589,500	37.85	568,500	36.50	548,500	35.25	527,500	33.90
30	770,500	49.50	746,000	47.90	721,500	46.30	696,500	44.75	671,500	43.20
40	865,500	55.60	838,500	53.80	810,500	52.10	783,500	50.30	756,000	48.60
50	915,500	58.80	886,000	56.90	857,000	55.00	827,500	53.15	798,500	51.30
60	944,500	60.60	914,500	58.70	883,500	56.75	853,000	54.80	822,500	52.80

TABLE X (C).

Annual Return on Investment. Undistributed Excess or Deficit. Freight Rate of $3.00 per 1000 Ton-miles.

Days per single voyage	Excess of income over disbursements or deficit									
	Fuel at $1 per bbl.		Fuel at $2 per bbl.		Fuel at $3 per bbl.		Fuel at $4 per bbl.		Fuel at $5 per bbl.	
	Dollars	%	Dollars	%	Dollars	%	Dollars	%	Dollars	%
STEAMSHIP, $1,250,000										
5	$ 239,000	19.12	$ 210,000	16.80	$ 181,500	14.52	$153,000	12.24	$124,000	9.92
10	594,000	47.52	553,500	44.28	512,500	41.00	471,500	37.72	430,500	34.44
20	969,000	77.52	912,500	73.00	856,500	68.52	800,000	64.00	744,500	59.56
30	1,111,500	88.88	1,046,500	83.68	981,500	78.48	915,500	73.20	850,500	68.00
40	1,145,000	91.60	1,073,000	85.84	1,002,000	80.16	930,000	74.40	858,000	68.64
50	1,113,000	89.04	1,037,000	82.96	961,000	76.88	886,000	70.88	810,000	64.80
60	1,040,000	83.20	960,000	76.80	881,000	70.48	802,000	64 16	723,000	57.84
MOTORSHIP $1,556,000,										
5	$ 237,500	15.27	$ 228,000	14.65	$ 219,000	14 10	$ 209,500	13.47	$ 200,500	12.90
10	616,500	39 40	602,500	38.70	588,500	37.80	574,000	36.90	559,500	35.90
20	1,065,500	68.40	1,044,500	67.10	1,023,500	65.75	1,003,000	64.30	982,500	63.15
30	1,300,500	83.50	1,276,000	81.90	1,251,500	80.40	1,226,500	78.75	1,201,500	77 50
40	1,439,500	92.40	1,412,500	90.70	1,384,500	88.90	1,357,500	87.10	1,330,500	85.50
50	1,511,500	97.20	1,482,500	95.20	1,453,500	93.30	1,423,500	91.40	1,394,500	89.50
60	1,554,000	100.00	1,523,500	97.90	1,493,000	95.90	1,462,500	93.90	1,432,000	92.00

TABLE XI.

Per Cent. Investment Return Compared

For

(a) Geared Turbine Single Screw 3500 S. H. P. Steam Auxiliaries

(b) Diesel Direct Twin Screw Diesel Electric Auxiliaries

Days per single voyage	Freight Dollars 1000 Ton-miles	Fuel $1.00		Fuel $2.00		Fuel $3.00		Fuel $4.00		Fuel $5.00	
		Turbine	Diesel	Turbine	Diesel	Turbine	Diesel	Turbine	Diesel	Turbine	Diesel
5	$1.00	-11.44	- 9.04	-13.76	- 9.64	-16.00	-10.23	-18.32	-10.83	-20.64	- 11.40
	2.00	3.92	4.40	1.60	3.79	- .68	3.21	-2.96	2.60	- 5.28	2.02
	3.00	19 12	15.27	16.80	14.65	14.52	14.10	12.24	13.47	9.92	12.90
10	1.00	- 1.60	- .35	- 4.88	- 2.50	- 8.16	- 2.15	-11.76	- 3.09	-14.72	- 4.02
	2.00	22.96	19.62	19.72	18.60	16.44	17.83	13.16	16.90	9.88	15.95
	3.00	47.52	39.40	44.28	38.70	41.00	37.80	37.72	36.90	34.44	35.90
20	1.00	8.80	10.00	4.28	8.64	- .20	7.28	- 4.68	6.04	- 9.16	4.59
	2.00	43.16	39.20	38.64	37.85	34.16	36.50	29.68	35.25	25.20	33.90
	3.00	77.52	68.40	73.00	67.10	68.52	65.75	64.00	64.39	59.56	63.15
30	1.00	12.84	15.45	7.64	13.88	2.44	12.30	- 2.84	10.70	- 8.04	9.10
	2.00	50.88	49.50	45.68	47.90	40.48	46 30	35.20	44.75	30.00	43.20
	3.00	88.88	83.50	83.68	81.90	78.48	80 40	73.20	78.75	68.00	77.50
40	1.00	13.92	18.75	8.20	17.00	2.48	15.20	- 3.24	13.45	- 9.00	11.70
	2.00	52.74	55.60	47.04	53.80	41.32	52.10	35.60	50.30	29.84	48.60
	3.00	91.60	92.40	85.84	90.70	80.16	88.90	74.40	87.10	68.64	85.50
50	1.00	13.20	20.50	7.12	18.60	1.04	16.75	- 5.00	14.85	-11.04	13.00
	2.00	51.12	58.80	45.04	56.90	38.96	55.00	32.92	53.15	26.88	51.00
	3.00	89.04	97.20	82.96	95.20	76.88	93.30	70.88	91.40	64.80	89.50
60	1.00	11.32	21.50	4.96	19.60	- 1.36	17.60	7.68	15.65	14.00	13.70
	2.00	47.24	60.60	40.88	58.70	34.56	56.75	28.24	54.80	21.92	52.80
	3.00	83.20	100.00	76 80	97.90	70.48	95.90	64.16	92.00	57.84	92.00

TABLE XII.

Freight Rates.

Data from "MARINE REVIEW," April, 1921.

Zone	Place	Distance, miles	General cargo	Heavy products, limited length	Per 1000 ton-miles	
					General	Heavy
England	London	3442	$ .75 per 100 lb.	$ 8.00 per ton	4.88	2.33
North Sea	Christiana	3771	1.25 per 100 lb.	10.00 per ton	7.43	2.65
	Rotterdam	3488	1.00 per 100 lb.	6.00 per ton	6.42	1.72
	Antwerp	3487	.80 per 100 lb.	5.00 per ton	5.13	1.43
Mediterranean	Marseille	3913	22.00 per ton	12.00 per ton	5.63	3.07
	Naples	4200	1.00 per 100 lb.	12.00 per ton	6.40	2.86
	Constantinople	5044	26.00 per ton	18.00 per ton	5.15	3.87
S. Africa	Capetown	6786	27.00 per ton	20.00 per ton	3.98	2.95
S. America, E.	Buenos Aires	3871	20.00 per ton	12.00 per ton	3.40	2.04
	Rio Janerio	4770	22.50 per ton	16.50 per ton	4.71	3.46
S. America, W.	Valparaiso	4633	1.33 per 100 lb.	16.00 per ton	6.39	3.45
Australia	Sydney	9691	25.00 per ton	15.00 per ton	2.58	1.55
India	Calcutta	9834	21.00 per ton	18.00 per ton	2.13	1.83

in Table XII, with each other for a number of scattered ports, and with the corresponding rates for general cargo.

The former are more consistent and charges lower, and range from about $1.50 to $3.50, with $2 as a fair average. When the ship has less than a full cargo, all conclusions drawn for full cargos apply with equal force to a correspondingly lower rate. For example, if conclusions are drawn on a $3 freight rate, assumed for a full ship, and the ship sails full one way, returning in ballast, or carries half cargo both ways, then the effect can be judged from the curves for a rate of $1.50 applied to full cargo. Normally,

TABLE XIII.

Fuel Oil—Present Indicative Prices.

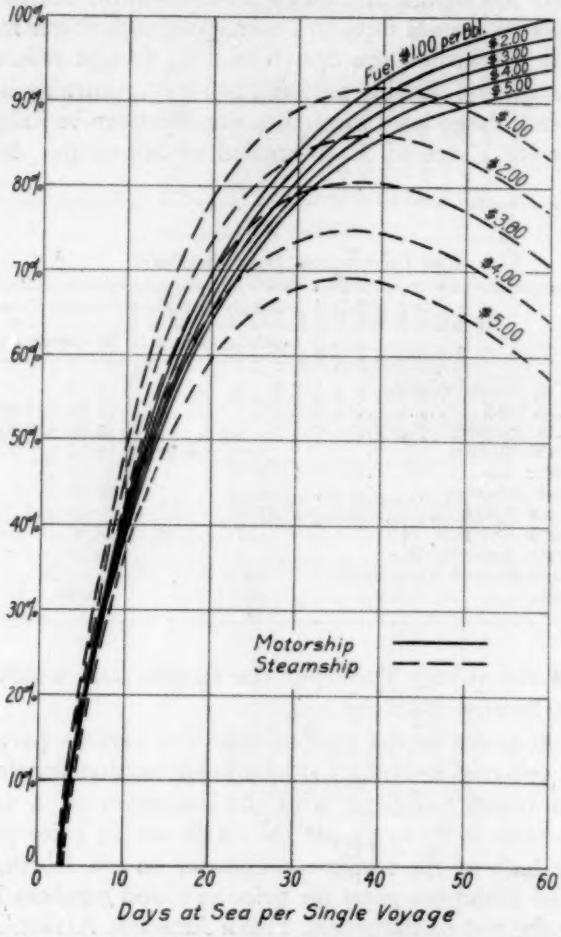
Zone	Cost per American bbl. 42 gals. Dollar	
	Oil Company A	Oil Company B
U. S. North Atlantic	.....	3.10
U. S. Gulf	.....	1.35 – 1.85
U. S. Pacific	.....	2.00 – 2.85
Great Britain	4.02 – 4.59	4.14
North Sea	4.82	.....
Mediterranean	4.31	6.06
South Africa	5.54	.....
South America, E.	5.01 – 5.46	5.40
South America, W.	.....	5.00
Australia and Australasia	5.75	.....
Asia	5.01	6.06

the longer the voyage the lower the freight rate, which is as it should be, because costs are less.

Fuel oil prices at the present time for various parts of the world are collected in Table XIII, and indicate that for the United States, in round numbers, with the exception of a few Gulf ports, the price is $2 to $3 per bbl., with the $3 price prevailing where the bulk of the traffic concentrates on the North Atlantic coast. For European ports the price in round numbers is $4 per bbl. For the rest of the world, South America, Africa, Asia and Australia, the price is $5 or over. These are the significant price ranges, *i.e.*, $3 to $5 per bbl., and former prices of $1 per bbl. or less no longer have any importance. An analysis of fuel oil prices in the past will indicate a steady rise and in recent years a rise controlled by the demand for automobile gasolene, such

that fuel oil follows gasolene in price at a pretty constant fraction, and probably always will do so. The future trend is definitely upward in spite of fluctuations natural to alternations

FIG. 10.



Annual Return on Investment with Freight Rate of $3.00 per 1000 Ton-Miles.

of business activity or stagnation. For these reasons the higher prices are the most significant in drawing conclusions as to the future with regard to the relative earning capacities of the different types of ships *over their life periods.*

Conclusions can now be drawn from the figures for investment returns of Table X and the corresponding superimposed curves of Figs. 8, 9, 10.

Starting with the fuel price of $3 per bbl. and a freight rate of $1 per 1000 ton-miles, it appears that the steamer shows a loss for voyage lengths less than 20 days, and the motorship for less than 10 days. The motorship is consistently the more profitable, yielding returns, compared to the steamer, increasing with length of voyage, 12.3 per cent. *vs.* 2.4 per cent. for 30 days, 15.2 per cent. *vs.* 2.5 per cent. for 40 days, 16.8 per cent. *vs.* 1.0 per cent. for 50 days, and 17.6 per cent. *vs.* a loss of −1.4 per cent. for 60 days, respectively.

For the $2 freight rate, the steamer shows a loss under 5 days, and the motorship no loss. The motorship earnings compete with the steamer on about equal terms, with the latter a little better for voyages of 20 days or less, after which the motorship earnings increase over the steamer, the relation being, 52.1 per cent. *vs.* 41.3 per cent. for 40 days, 55 per cent. *vs.* 39.0 per cent. for 50 days, and 56.7 per cent. *vs.* 34.6 per cent. for 60 days.

With a $3 freight rate, the two ships are competitive on about an equal earning basis for voyages up to about 30 days, after which the motorship earnings increase over the steamer, the figures being, 89 per cent. *vs.* 80 per cent. for 40 days, 93 per cent. *vs.* 77 per cent. for 50 days, and 96 per cent. *vs.* 70 per cent. for 50 days.

At the higher fuel price of $4 per bbl. for fuel oil, the competitive zone is narrowed to shorter voyages at corresponding freight rates.

For a freight rate of $1, the steamer shows a loss for any length of voyage and the motorship for less than 10 days. The motorship returns increase regularly beyond, 6 per cent. for 20 days, 11 per cent. for 30 days, 14 per cent. for 40 days, 15 per cent. for 50 days and 16 per cent. for 60 days' voyage.

Freight rates of $2 reduce the steamer losses to less than 5 days and eliminate loss of the motorship. The motorship is consistently more profitable over the whole range, as shown by the figures: 17 per cent. *vs.* 13 per cent. for 10 days, 35 per cent. *vs.* 30 per cent. for 20 days, 45 per cent. *vs.* 35 per cent. for 30 days, 50 per cent. *vs.* 36 per cent. for 40 days, 53 per cent. *vs.* 33 per cent. for 50 days, 55 per cent. *vs.* 28 per cent. for 60 days.

A further increase of freight rates to $3 widens the competitive

zone further, the two ships being on about an equal basis for voyages less than 20 days beyond which the motorship is increasingly profitable, the figures being, 79 per cent. *vs.* 73 per cent. for 30 days, 87 per cent. *vs.* 74 per cent. for 40 days, 91 per cent. *vs.* 71 per cent. for 50 days, and 94 per cent. *vs.* 64 per cent. for 60 days.

Taking the fuel oil price of $5 per bbl. the importance of economy is greater.

For a freight rate of $1, the steamer shows a loss for any length of voyage, but the motorship yields net returns for voyages in excess of 10 days, and in increasing amounts, the figures being 5 per cent. for 20 days, 9 per cent. for 30 days, 12 per cent. for 40 days, 13 per cent. for 50 days and 14 per cent. for 60 days.

Freight rates of $2 eliminate the steamer losses for voyages over 5 days and increase the motorship profits materially over the steamer, the figures being, 16 per cent. *vs.* 10 per cent. for 10 days, 34 per cent. *vs.* 25 per cent. for 20 days, 43 per cent. *vs.* 30 per cent. for 30 days, 49 per cent. *vs.* 30 per cent. for 40 days, 51 per cent. *vs.* 27 per cent. for 50 days, 53 per cent. *vs.* 22 per cent. for 60 days.

Finally at $3 freight rate, the motorship is consistently more profitable than the steamer over the whole range of voyage lengths, the figures being, 13 per cent. *vs.* 10 per cent. for 5 days, 36 per cent. *vs.* 34 per cent. for 10 days, 63 per cent. *vs.* 59 per cent. for 20 days, 78 per cent. *vs.* 68 per cent. for 30 days, 86 per cent. *vs.* 69 per cent. for 40 days, 90 per cent. *vs.* 65 per cent. for 50 days, 92 per cent. *vs.* 58 per cent. for 60 days.

This analysis proves conclusively the practicability of this method of analysis, and fixes the competitive and non-competitive zones in terms of voyage lengths for the two forms of present new standards of ship propulsion with geared turbine steamer, single-screw, with steam auxiliaries, and the twin-screw motorship with direct-coupled Diesel engines and Diesel electric auxiliaries. It clearly shows the importance of freight rates and fuel prices, on the relative profitable zones of operation. High fuel prices and low freight rates favor the motorship as do also long voyages.

One most remarkable conclusion is that the motorship has a very sharply defined zone in which the turbine steamer cannot compete at all, the long voyage, low freight rate, high fuel price zone. On the other hand, there does not appear to be any such

well defined zone where the steamship could be said to dominate. The steamship economic zone is that of short voyages, of a few days at normal freight rates and fuel prices, and even for these conditions the motorship returns are never very much below the steamer. This means in effect that when the motorship does not control, it is at least competitive actually or so very nearly so unless fuel prices fall very low, less than a dollar per barrel.

When the length of voyage is very short, only a few days, a condition that favors the steamer over the motorship, it must be remembered that the ratio of port time to sea time becomes so abnormally large as to lead inevitably to the conclusion that such a large ship as is under consideration, 10,000 D.W.T., is unsuited to the service, which really requires a smaller vessel, small enough to shorten port time to an acceptable value. As ships grow small, 5000 D.W.T., and less, the oil engine has proportionately greater advantages over steam. It is only in those cases where the conditions keep a ship in port most of the time that the cheapest kind of steamer is the only thing that will meet the requirements, and fuel expense at sea becomes a minor item, with a good probability that coal-fired boilers must be used.

Changes in expense items due to different estimates of quantities and prices from those used will have the effect of changing the competitive zones of the two types of ships under analysis by a few days, but will have no other effect on the general conclusions that have been reached as to relative economic zones.

(To be concluded)

The Wave-length of Hard Gamma Rays. A. H. COMPTON. (*Phil. Mag.*, May, 1921.)—A new method for the calculation of wave-lengths is developed, which depends upon the finding of an angle at which the ratio of the gamma rays scattered from lead to those scattered from copper is the same as the ratio of X-rays scattered at 90° from lead to those scattered from copper. When this angle has been found a simple formula gives the desired wave-length, provided the wave-length of the X-rays is known. There are elements of uncertainty in the process, but the author feels justified in giving for the wave-length of hard gamma rays that have traversed 8 mm. of lead the quantity .025 to .030 angstrom units. This is only about one two-hundred-thousandths of the wave-length of sodium light. (An angstrom unit is one ten-millionth mm.) G. F. S.

Manufacture of Engines, Steam, Gas and Water.—A preliminary statement of the 1920 census of manufactures with reference to the manufacture of engines, steam, gas and water, has been prepared by the Bureau of the Census, Department of Commerce. It consists of a detailed statement of the values of the various products manufactured during the year 1919.

The figures are based on returns from 371 establishments with products for the year valued at $464,770,000. At the census of 1914 there were 446 establishments with products valued at $72,121,000.

In 1919, 44 establishments were located in Ohio; 36 in Wisconsin; 35 in Michigan; 34 in Pennsylvania; 31 in New York; 25 in Illinois; 22 in California; 17 in Iowa; 16 each in Connecticut and Indiana; 15 in New Jersey; 14 in Minnesota; 13 in Washington; 10 in Missouri; 5 in Kansas; 4 in Massachusetts; 3 each in Colorado, Maine, Maryland, Oregon, and Texas; 2 each in Kentucky, Nebraska, and New Hampshire; and 1 each in Alabama, Arkansas, Delaware, Florida, Louisiana, North Dakota, Oklahoma, Rhode Island, South Carolina, South Dakota, Tennessee, Vermont, and Virginia.

Of the total establishments under this classification the chief product of 60 was steam engines; of 199, internal combustion engines; of 85, traction engines; of 10, water wheels, motors, turbines and hydraulic rams; and of 17, locomotive engines, parts of engines and locomotives, and other foundry and machine shop products and repairs.

World's Largest Deposit of Rock Salt.—Vast quantities of rock salt lie less than half a mile beneath the surface of the earth in the United States. In New York, Ohio, Michigan, Pennsylvania, West Virginia, and other States there are large deposits, but the largest deposit in the United States, and probably in the world, is that which extends from northern Kansas across the west end of Oklahoma, the panhandle of Texas, and southeastern New Mexico to western Texas. The area underlain by these great Permian salt deposits is not far from 100,000 square miles, according to the U. S. Geological Survey. The limits of the deposit, especially to the northwest and southeast, have not been ascertained, but in general the area of thick salt extends fully 650 miles from northeast to southwest, and is 50 to 150 miles wide. The thickness and the succession of the beds are variable, but 700 feet is reported in one hole, and in many places the aggregate is more than 300 feet. On the assumption of an average thickness of 200 feet of salt, the gross quantity in the area of 100,000 square miles is so large, about 30,000 billion tons, that the present needs of the United States (about 7,000,000 tons a year) can be supplied for millions of years.

LEONARDO DA VINCI—NATURAL PHILOSOPHER AND ENGINEER.* †

BY

JOHN W. LIEB, M.E.

Vice President, the New York Edison Company. Member of the Institute.

We have no single architectural structure which can be claimed as the authentic work of Leonardo, although his manuscripts are full of sketches and plans for all kinds of buildings, public and private. We have some reason to believe that he coöperated with Bramante in the planning of several buildings, and we have definite knowledge that he made plans and acted as a consulting architect on the Cathedral at Milan and that he executed the frescos recently restored in some of the rooms of the Castello Sforzesco, Milan, and probably did some of the planning on that formidable medieval castle-fortress. We also know that he was frequently consulted as an expert in building, and he has written many notes on the construction of foundations and the causes of fissures and cracks in walls. In his introduction to these notes he says: "First write the treatise on the causes of failure of walls and then separately treat of the remedies." Of foundations, Leonardo says:

"The first and most important thing is stability. As to the foundations of the component parts of temples and other public buildings, the depths of the foundations must bear the same proportions to each other as the weight of the material which is to be placed upon them." BM Fol 138a

And again:

"That beam which is more than twenty times as long as its greatest thickness will not last long, but will break in half; and remember that the part built into the wall should be steeped in hot pitch and filleted with oak boards likewise so steeped. Each beam must pass through its walls and be secured beyond the walls with sufficient chaining, because in consequence of earthquakes the beams are often seen to come out of the walls and bring down the walls and floors. Again I remind you never to put plaster over timber, since by expansion and shrinking of the timber produced by damp and dryness such layers often crack, and once cracked their separation gradually produces dust and an ugly effect." Ms A Fol 53a

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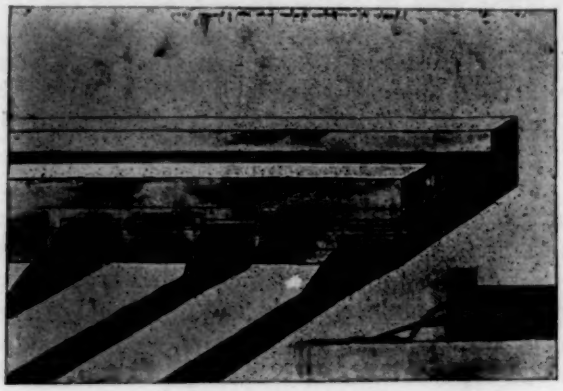
* Presented at the Annual Meeting of the Institute held Wednesday, January 19, 1921.

† Concluded from page 806, vol. 191, June, 1921.

We have sketches in perspective and some in plan and elevation showing the internal arrangements of palaces and villas, sketches of several battlemented castles, an elaborate mausoleum, a project for raising the Baptistry of Florence, and a great number of churches and Basilicas.

Leonardo also made a most interesting study of city planning, including a plan for a town with a double system of high level and low level roadways. In this connection we find a suggestive note:



Canal of S. Cristoforo, Milan. Measurement of water.

"Let the street be as wide as the average height of the houses." Ms B Fol 36r

This dream of a model city is thus referred to:

"The model cities will be served by two kinds of streets; highways elevated or on a slope, elegantly ornamented and perfectly clean; and lower or subterranean roadways, washed from time to time by limpid water from the watercourse, and from which the refuse will be removed with rakes.

In such a way that whoever wishes to travel by the elevated highway may do so at will; and also whoever wants to go by the lower route will be free to do so. Vehicles will never make use of the upper highway, reserved for gentlemen; while in the lower street the wagons and beasts of burden for work and for the supplies of the people will circulate." Ms B Fol 16r

The plague had ravaged Milan during the years 1484 and 1485, causing the death of over 50,000 people and destroying all commerce and all activity; Leonardo wished to reconstruct the city and the surrounding towns which had been decimated by the scourge and he wrote to the Duke:

"Lay out again 5000 houses among 10 cities, corresponding to 30,000 lodgings and you will thus split up the masses of population that now crowd together like goats, side by side, scattering over all the fetidity and the pestilential germs of death. The cities will be beautiful and you will be honored for it forever." Ms CA Fol 65v

A careful study of the notes and sketches shows that Leonardo devoted considerable time and thought to the elimination of unnecessary work in construction, and to obtaining the maximum result with a minimum of effort; in reality this is what we term to-day motion study as applied to the industries.

We find many references to the excavation by machines and men of canals and trenches, and that he did not neglect the smallest detail is shown by diagrams of ditch digging on four levels, the men being shifted from one level to another so that each man will not be performing the most laborious work all of the time. And this, he says, "gives better results."

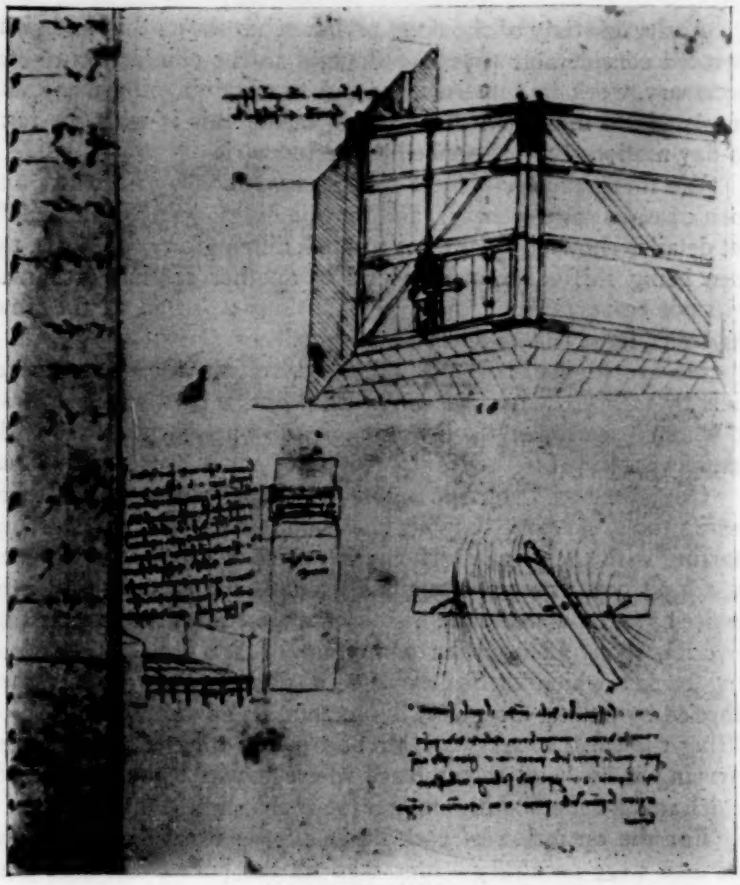
He investigated also the motions involved in carrying materials by means of carts, and a century and a half before Pascal, to whom is attributed the invention of the wheelbarrow, Leonardo actually applied it in the transportation of earth, stones and water.

One sheet of Leonardo's notes contains, among other excavating tools, sketches showing the evolution of the wheelbarrow, starting with the primitive form, in which the load was fastened to a long pole dragged along the ground, and leading up to the device as we now make use of it. It is interesting to note that he describes many methods in common use to-day, such as the travelling bucket which carries earth to a desired place and is then emptied by pulling a rope. This method he advocated, instead of lifting the earth to an upper level by means of a winch and then carrying it by hand to the place where it was to be discharged, which was the method in common use at that time.

For the operation of each crane of the excavating machine, six men were necessary—four who fill the bucket and two who bring down the counterweight by the weight of an ox, thus raising the bucket. The bucket empty and the crane turned, the bucket is then swung around and lowered again to the bottom. The lower figure shows another stairway which Leonardo says is better, since being curved, its base is half the distance from the foot of the crane that the straight stairway is, and the ox can make an increased number of trips a day.

A hundred years before Galileo, who previously was accredited with this service to structural mechanics, Leonardo made careful investigations on the strength of materials.

In his treatise Leonardo states that the load capable of being



Canal lock of S. Mark.

carried by a cantilever is inversely proportional to the distance from the load to the point of support.

He says:

"If you place upright a support of uniform thickness and material, which will resist a weight of 100, and you then take 9-10ths of the height away, you

will find that the rest when stood on end will resist a weight of 1000." Ms CA Fol 152 and 211

And of horizontal beams loaded at the centre:

"You will find a similar strength and resistance in a bundle of nine beams of equal cross section, as in the one-ninth part of one of them." Ms CA Fol 152 and 211

And to test the strength of wire Leonardo shows a crude wire-testing machine in which the weight is applied gradually by means of sand dropping into a pail.

HYDRAULIC ENGINEERING.

Leonardo's work in Hydraulic Engineering was of a theoretical as well as a practical character, and the results of his experiments and observations are embodied in the treatise "On the motion and measurement of water," a complete text-book on hydraulics which treats nearly every phase of the subject. The science of hydraulics had its birth in Italy and Venturi says of da Vinci's work: "Not only did he observe all that Castelli wrote about the movement of water a century later, but he was his superior, although Castelli has until now been considered the founder of hydraulics."

He begins his treatise in truly modern style with an index of subjects, a series of definitions of the terms used and a vocabulary of technical words and phrases.

It treats of the physical properties of water, the forms it assumes as clouds, rain and drops, the flow of water in canals and rivers, the distribution of the currents caused by the shape of the river bed and shores, the formation of waves, vortices, whirlpools and eddies, and the measurement of the velocity and volume over weirs and through orifices.

The illustrations of the complicated figures which water makes when it is contracted into whirls and eddies flowing from a spout, a discharge nozzle or over a dam into a basin or river with the various interference currents, counter-currents and reflected waves, cover many pages of his notes.

His studies cover also the erosion of river banks and methods of protecting water courses, the transportation of rocks, gravel and sand from the mountains to the sea, and a discussion of methods of measurement and finally the application of pumps of

every conceivable kind, Archimedian screws, chain and bucket lifts, and even the beam type of suction pump with double acting valves, for the elevation of water and the reclaiming of marsh lands, all these investigations and plans being directed into practical channels, as witness their extensive application by him in canals for irrigation and transportation with their locks, gates and distribution sluices.

Leonardo was appointed water register for Lombardy by the King and he obtained as a gift the right to divert a certain quan-

Sprocket chains.

tity of water from the St. Cristoforo Canal, Milan, part of which he expected to sublet and part to be used for irrigation on his own property, and he refers to this franchise grant as follows:

"If it is said that the income of the King is reduced 72 ducats by taking that water from St. Cristoforo, His Majesty knows that what he gives to me he takes from himself, but in this case nothing is taken from the King, but taken from those who have stolen, because in arranging the sluices they have stolen the water by enlarging them." Ms CA Fol 93r

We find many interesting sketches of waterways and canals crossing over rivers on special arched bridges, and he presents plans for extensive reclamation work in Tuscany, inland waterways and a plan for the Romortin Canal in France, which was

actually carried out in accordance with his scheme centuries later.

An interesting note on canal construction merits translation in full. Referring to the Romortin Canal in France:

"The water may be dammed up above the level of Romortin to such a height, that in its fall it may be used for numerous mills. The river at Villefranche may be conducted to Romortin which may be done by the inhabitants; and the lumber of which their houses are built may be carried in boats to Romortin. The river may be dammed up to such a height that the waters may be brought back to Romortin with a convenient fall." Ms BM Fol 269b

And also on the Canal of Florence:

"Sluices should be made in the valley of La Chiana at Arezzo, so that when, in the summer, the Arno lacks water, the canal may not remain dry; and let this canal be 20 braccia (yards) wide at the bottom and at the top 30, and 2 braccia deep, or 4, so that 2 of these braccia may flow to the mills and the fields which will benefit the country; and Prato, Pistoia and Pisa, as well as Florence, will gain two hundred thousand ducats a year, and will lend a hand and money to this useful work; and Lucca the same, for the Lake of Sesto will be navigable; I shall direct it to Prato and Pistoia and cut through Serravalle and make an issue into the lake; for there will be no need of locks and supports, which are not lasting and so will always be giving trouble in working at them and keeping them up." Ms CA Fol 45a–140a

"If it be not reported that this is to be a public canal it will be necessary to pay for the land; and the King will pay it by remitting the taxes for a year." CA 233a; 700a

He gives illustrations and describes in notes various kinds of divers' helmets and air hose for the use of divers, life preservers and queer devices for swimming and walking on the water. In this connection he says:

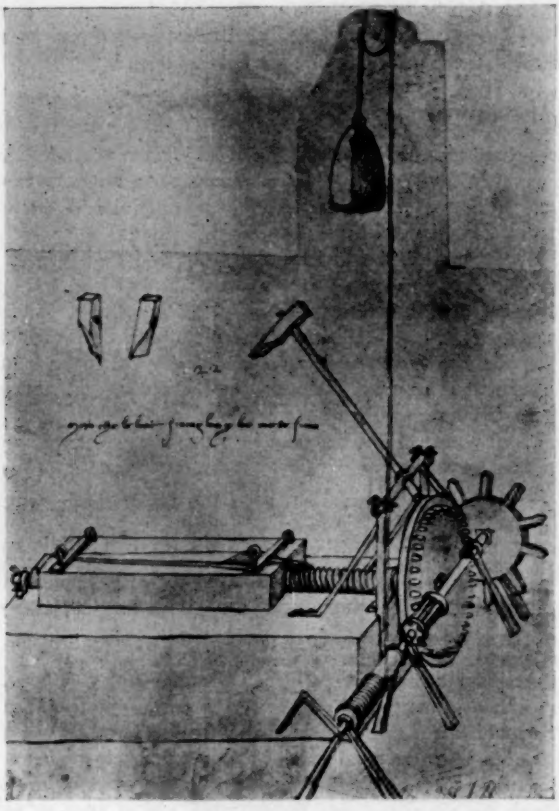
"It is necessary to have a coat made of leather with a double hem over the breast the width of a finger and double also from the girdle to the knee and let the leather of which it is made be quite air-tight. And when you are obliged to jump into the sea, blow out the lapels of the coat through the hems at the breast and then jump into the sea. And always keep in your mouth the end of the tube through which the air passes into the garment, and if once or twice it should become necessary for you to take breath when the spray prevents you, draw it through the mouth of the tube from the air within the coat." Ms B Fol 81b

MECHANICAL ENGINEERING.

In the field of mechanical engineering, particularly, Leonardo did a vast amount of what seems to have been pioneer work, and the engineer of to-day in studying his notes and drawings, becomes deeply impressed with the close touch in which he is put with

this earliest of mechanical engineers, through the medium of that international engineering language, a working mechanical drawing.

While we find in the ancients a knowledge and application of the elemental mechanical movements, the lever, the inclined plane, the pulley and the screw, and to an extent their simple combina-



File cutting machine.

tion, it is in the work of this master mind that we first reach the full fruition of mechanical genius.

In his work we first find exemplified complex mechanical movements of the most ingenious kinds, then their combination to achieve desired motions and finally, their coördination into a complete working machine, the various functions of the machine correlated by appropriate mechanism, often automatic in its opera-

tion, for let it be said he was indeed the very first, as far as we know, to introduce the really modern element of automaticity into his machines.

The improvements suggested in machines having an axis of rotation are of marked interest, for he designed shafts to turn not only in adjustable stationary bearings, but with roller bearings as we have them to-day, to reduce friction. Flexible chain or sprocket drive are among his inventions and they are clearly shown on several sheets of the Codice Atlantico together with flat chains of even mesh, not soldered, flexible only in the two opposite directions, to be used instead of belts for the transmission of power in machines.

The character of his sketches of cranks, pins, couplings, cams, friction clutches and gears show that the subject of our address had for his time a remarkably accurate knowledge of machine design and construction, and some of the framework and supports of his apparatus are of excellent design.

We have among his sketches a remarkable series of machines to only a few of which reference can be made:

An automatic file-cutting machine presents interesting details including the mechanism for feeding forward the steel blank as the teeth are cut, the hammer heads for various cuttings, the mechanism for operating the machine by a heavy falling weight, etc. We find illustrated several machines, horizontal and vertical, for drilling pump logs excellently designed like a modern boring lathe, and remarkable to relate, one of the forms shows an automatic geared chuck, a modern tool that was reinvented and patented as new not so many years ago.

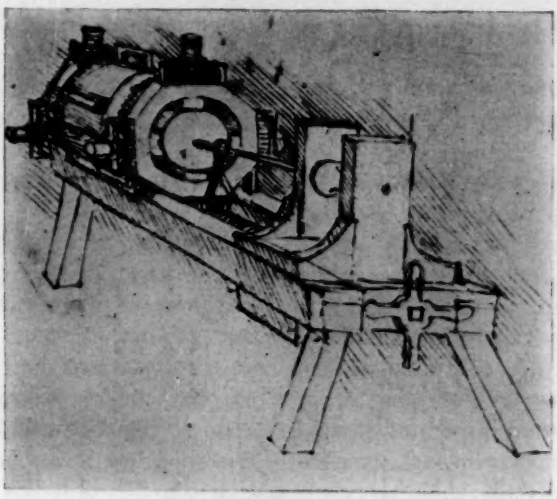
A truly wonderful piece of mechanism is the machine driven, as shown, by a turbine water wheel for drawing tapering trapezoidal iron bars for built-up cannon in which should be noted particularly the feeding mechanism and the helicoidal rotating die for producing the taper and the trapezoidal draw blocks. We find sketches of many machines for drawing wire, bars and flat springs.

Many sketches illustrate grinding machines of various kinds for grinding colors and for grinding lenses of different focal lengths and even parabolic lenses. Leonardo invented the three-legged folding stool, the hinge with spiral spring for automatically shutting the door, secret or unpickable locks, rotating chimney tops for smoke pipes, and a turnspit operated by hot air, of which

he says: "This is the true turnspit because according as the fire is moderate or not, the roast will turn quickly or slowly." Ms CA Fol 5va

We have also various types of windlasses, capstans and cranes; mechanical presses, machines for weaving ribbon, for cutting cloth, and for spinning silk and linen.

He produced a complete set of coin stamps for the Royal Mint at Rome and shows the blanks and describes their manipulation. We also find rolling mills for sheet lead, several kinds of turning



Boring mill for pump logs.

lathes operated by weights and by foot power, various kinds of saws for stone and wood operated by crank and connecting rod and with flywheels to secure uniformity of motion.

He speaks of the use of the pendulum as a speed regulator; shows an automatic printing press, a drop or punching press, screw-cutting machines to cut screws of various pitches with a master screw and cutting tool and change gears, rope-making machinery and complicated machines for pointing needles.

In the textual notes, accompanying many of these machines, some having no marginal notes with the purpose of the machine therefore sometimes left in doubt, appear some interesting reflections as to the power taken by the machines and other peculiari-

ties, for instance: "These machines must be driven by water power, for when they are turned by hand they go so slow that the work is not effective," and "Because without experiment a correct understanding of the power with which the drawn iron resists the die cannot be obtained, I have made in the doubtful parts four wheels with endless screws, by means of which anyone can tell by observing their size what power the combination has."

"If you do not wish to multiply the number of teeth of the wheels, then increase their size, which will give the same thing." "The rope for the above hydraulic machine must be of iron or annealed copper wire, otherwise it is of little strength; and the above mentioned wire must be of the thickness of a bow string."

He occupied himself much with the design and construction of spinning machinery and in all of his designs it is clear that he laid special emphasis on the relative motions of the spindle and the spool.

Leonardo is believed to have been the inventor of the flyer, operating in conjunction with the spindle for twisting the yarn in the process of winding it on the bobbin as used in the present-day spinning frames.

It is certainly remarkable that use was made of the reverse spindle and spool movements quite as they are used to-day in our automatic machines and that he understood how to combine the rotating motion of the spindle with an alternating motion.

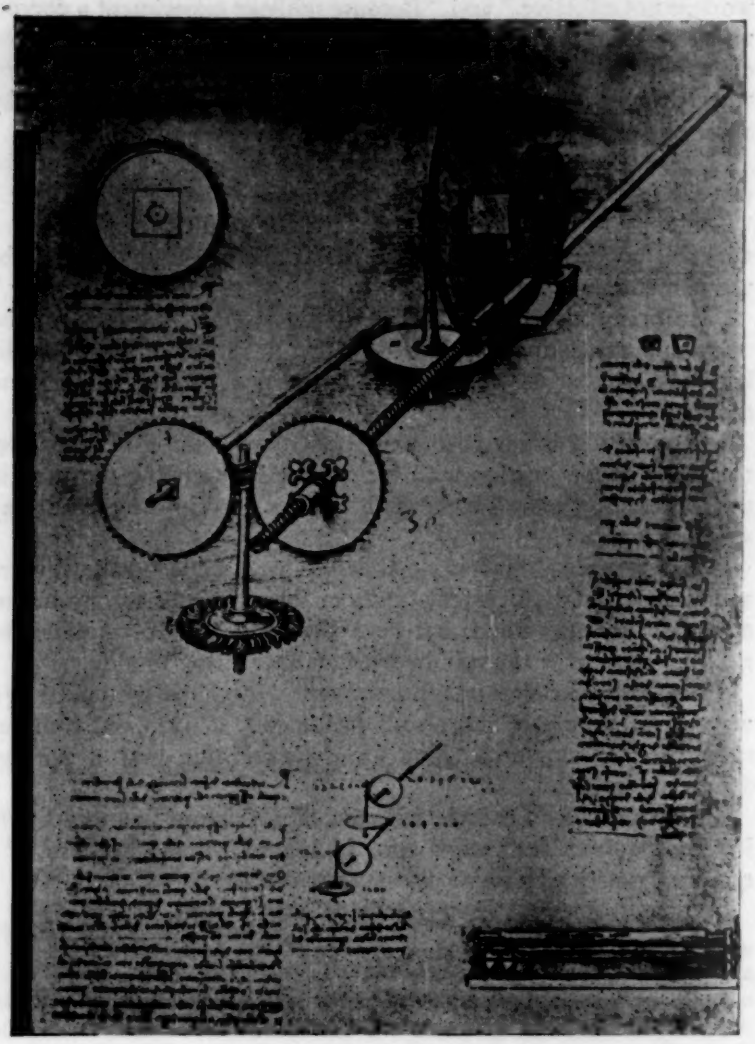
He shows sketches of a hygrometer, a cyclometer applied to a wagon, an adometer and also a pedometer, a universal compass suspension, a universal joint, a dynamometer and a spring-driven automobile!

We have also a complete sketch of a friction fire escape, re-invented only a few years ago, in regard to which there is a marginal note which says:

"This device is made to enable one to drop quickly from great heights without danger of fall. The rope—c, d—is given three turns around the screw—a, b—. This screw is 1/2 elle long and 1/12 elle thick. This is then covered with the cylinder—e, f—thus tightening the grip and increasing the friction which allows of only a slow drop when one hangs on the screw." Ms CA Fol 112rb

We should also note the designs of several types of water wheels overshot and undershot and also a diagrammatic sketch of a pressure water turbine.

Enough has been said to show what a marvelous range is covered by these sketches and mechanical drawings, many of them



Machine for drawing bars for cannon.

in perspective and executed with great precision, not only as to their draughtsmanship, but as to their good proportioning of parts and general excellence of design from an engineering standpoint.

ARTIFICIAL FLIGHT.

And now we come to a most interesting field—a very new and modern field—in which Leonardo did wonderful work, imaginative and speculative perhaps, but full of acute observation and experiment, a field in which he stopped just short of attaining practical results owing to the lack of that most important key to the solution of many of our problems of to-day and which has made possible the automobile, the dirigible, the aëroplane, and the speed boat—the internal combustion motor.

We refer to Leonardo's work in the field of artificial flight. In no other direction has he shown such a combination of the extraordinary powers he possessed of scientific research, acute observation and mechanical ingenuity. Without the internal combustion motor we have to-day, aviation would be just about where he left it, with the possible exception of the work done on gliders by Chanute and Lilienthal.

If we were to go into the details of his observations on the flight of birds, and every creature that flies, his researches and investigations on wind pressure, shape of wings, balancing, etc., the design and suggestion for flying machines with the wealth of details of construction of wings and tails and operating mechanism as revealed in his numerous sketches and notes, we should take up for this department alone of Leonardo's activities the time for several addresses.

We find illustrations and some text notes for flying machines with two and four wings, operated by one or more persons working together or in relays, using the arms and legs or both with the head and neck operating the steering gear or tail with the operator lying prone or standing vertically and with and without spring motors as the main or auxiliary propelling power.

We also find interesting sketches and a notable description of an altogether novel type of screw flying machine—the helicopter—which permits an almost vertical ascent, and a sketch, the first known appearance, of a parachute with descriptive details. His remarkable codex or "Treatise on the flight of birds" is full of the most accurate and careful observations on bird flight, with discussions and experiments on the sustaining power of the air, and the part which the adjustment of wings and their flexing, the adjustable tails and the various kinds and shapes of feathers take in the operations of gliding, soaring, balancing, rising, and

alighting before and against the wind. The sketches of the position of the body wings and tails of birds and insects in flight and their successive positions and warping of the wings show a keenness and accuracy of observation all the more remarkable in the absence of that most efficient modern aid to similar studies—the motion picture camera.

In the Codice Atlantico Fol 314r and the detail appearing on Fol 308r we find two remarkable sketches of the general plan and details of wing mechanisms of a real aeroplane, the

Flying machine wings.

wings operated by a powerful spring motor of which the construction appears clearly indicated with its bow springs, pulleys, countershaft, and even a speed regulator in the form of a fly-ball governor. It would appear that the operator was to stand vertically between the two main uprights rising from the horizontal platform where, in the small sketch assigned to the motor, clearly appear the words, written backwards of course—*Fundamento del Moto*—foundation of the motor.

Leonardo's pioneer work in the field of aviation would alone entitle him to the highest place as a scientist and engineer, for the science, skill and ingenuity he displayed in his endeavor to solve

one of the great problems of the ages, artificial flight, even though he may have achieved no practical results. The record of his work in this field lay dormant and unappreciated for nearly four hundred years, during which the only substantial progress made towards its solution is synthetized in the expression "Lighter than air machines." The importance of these marvelous records is not recognized by students of aviation problems even to-day, although emphasized by students of Leonardo like McCurdy, Beltrami, and others, and will only reach fruition when attention becomes again concentrated on human flight unaided by external power.

One or two quotations, literally translated, may here be of interest:

"One can exert as great power (pressure) with a body (wing) against the air as the air can exert against a similar body (wing).

You observe that wings swung against the air enables the heavy Eagle to float on the thin air of the mountains as he sails into the blue empyrean; as you observe also the air sweeping over the sea against the distended sails, drives forward the heavy ships, pushing back the air from the sails.

You can see therefore from these facts that man with his great artificial wings as he exerts his power against the air and overcomes its resistance can use this resistance as a lever and soar into the air." Ms CA Fol 372b; 1158b

"A bird is an instrument operating according to mathematical laws, this instrument it is within the power of man to be able to imitate with all of its motions but not relatively with so much power; it is lacking only in the power of balancing; therefore it can be said that such an instrument made for man lacks only the soul (will power) of the bird, for which it is necessary to substitute the soul (will power) of the man. This will power will be better (more promptly) obeyed by the individual members in the case of the bird, than by the will of the man which is separated from them and especially in the movements of almost imperceptible balancing, but as we can see the bird provide for the many evident varieties of movement, we can by that experience judge that the most evident motions can be understood by man and that he can largely provide against the destruction of that flying machine of which he has made himself the soul and the motive power." Ms 161ra

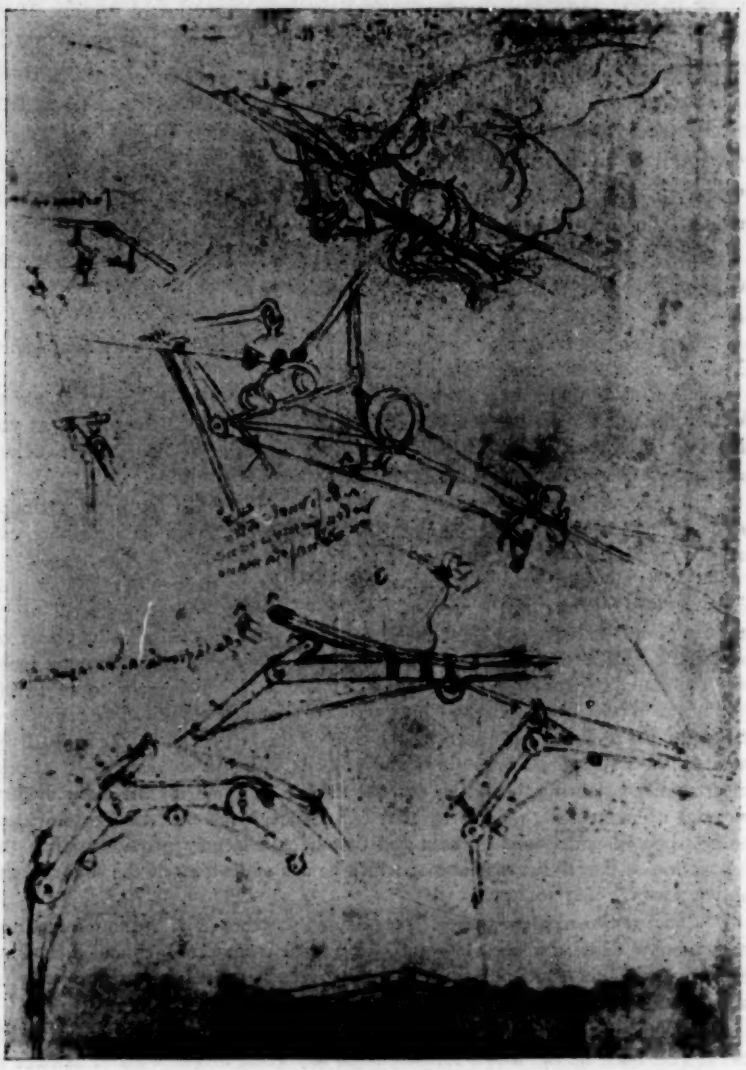
"Construct to-morrow figures (models) of pasteboard of various forms and make them to descend in the air by dropping them from a bridge; and then draw the curves and the motions which the fall of each makes in various parts of its descent."

"If a man has a canopy of water-proof canvas, that is 24 feet on each side and 24 feet high, he can throw himself from any great height without damage to himself." (Parachute) Ms CA Fol 381va

"Try which is greater in its effect, the weight of a man or the push of his legs." Ms Codice Sul Volo Degli Uccelli 17 [16] r

"I have divided the Treatise on Birds into four books: of which the first

treats of their flight by beating their wings; the second of flight without beating the wings and with the help of the wind (soaring); the third of flight in general,



Flying machine and details of construction.

such as that of birds, bats, fishes, animals and insects; the last of the mechanism of this movement." Ms K Fol 3r

"When the bird lowers one of its wings necessity constrains it instantly to extend it, for if it did not do so it would turn right over." Ms K Fol 4v "That part of the air which is the nearest to the wing which presses on it will have the greatest density." Ms K Fol 7r

"In testing flying machines do not fly too near the ground, for if you fall you will not have time to right your machine before hitting the ground." Ms Codice Sul Volo Degli Uccelli Fol 7v

"The imperceptible fluttering of the wings without any actual strokes keeps the bird poised and motionless amid the moving air." Ms CA Fol 308rb.

And so we could continue and fill a whole volume with quotations, but we cannot resist the temptation to add just one more observation which would seem to afford a definite indication that he must have actually flown, for otherwise he could hardly have been aware of an important observation when he says that the movement of the artificial bird should be "above the clouds in order that the wings be not damaged and that the danger from sudden gusts of wind be avoided, as in valleys there is always a gathering of the winds and of whirls and eddies," Ms Codice Sul Volo Degli Uccelli Fol 7v. This is the now well-known phenomena of air ridges and "air holes," a comparatively recent rediscovery as a result of the practical development of the aeroplane.

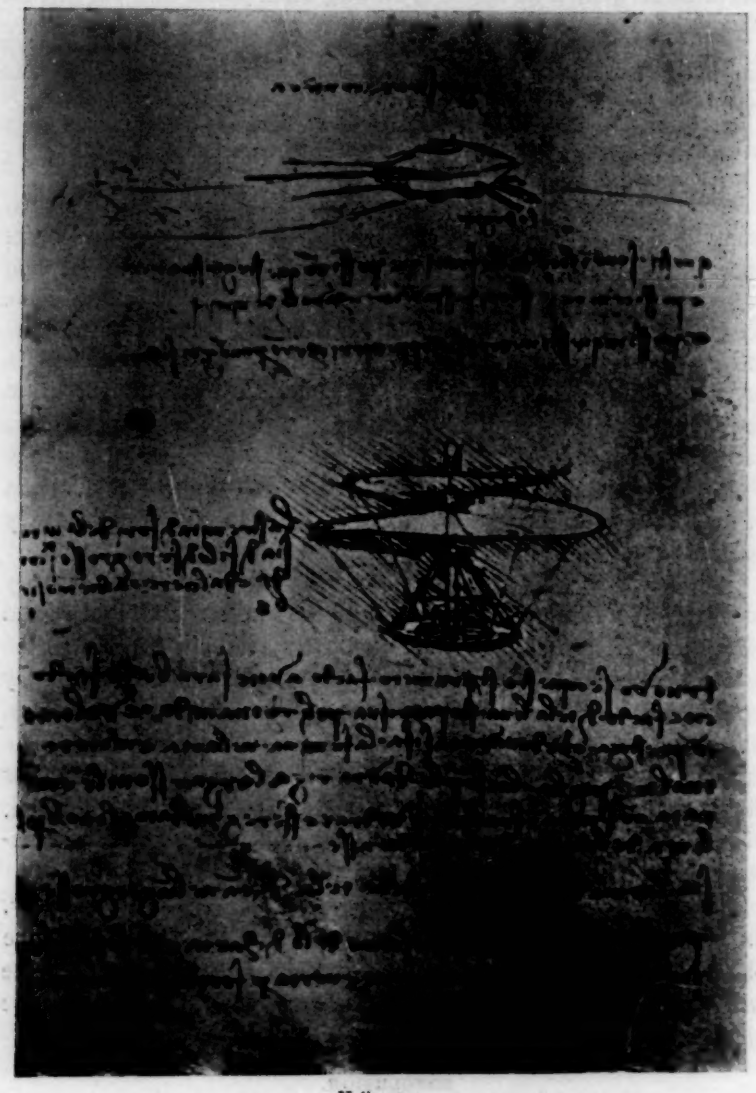
We have no positive knowledge that Leonardo did actually accomplish any flights, although there is some evidence that he did make some attempts, and like many others after him, was exposed to ridicule for it. We have an early reference in a contemporary work by Gerolamo Cardano (1501–1576) "De Subtilitate," in which, referring to "The excellent arts which are hidden" he says in reference to artificial flight: "It has turned out badly for the two who have recently made a trial of it. Leonardo da Vinci, of whom I have spoken, has attempted to fly but he was not successful; he is a great painter."

In one of his notes, Ms Codice Sul Volo Degli Uccelli Fol 18v, the great master says: "The first flight of the Big Bird will take place from the lofty Swan Hill (near Florence), and the universe will be filled with its praises and the nest whence it sprang will be filled with eternal glory."

CONCLUSION.

Jean Paul Richter in his two classical volumes on Leonardo da Vinci, says:

"It is due to nothing but a fortuitous succession of unfortunate circumstances that we should not long since have known Leonardo not merely as a



Helicopter.

painter, but as an author, a philosopher and a naturalist. There can be no doubt that in more than one department his principles and discoveries were infinitely

more in accord with the teachings of modern science than with the views of his contemporaries.

"For this reason his extraordinary gifts and merits are far more likely to be appreciated in our own time than they could have been during the preceding centuries. He has been unjustly accused of having squandered his powers, by beginning a variety of studies and then, having hardly begun throwing them aside. The truth is that the labors of three centuries have hardly sufficed for the elucidation of some of the problems which occupied his mighty mind."

We do not know to-day how many of Leonardo da Vinci's sketches and drawings were actually original designs or inventions, or how many were merely sketches to aid his memory of things he had seen. We do know that some small portion of the material referred to by Leonardo was not original with him, as he has often specifically mentioned that this or that device or idea was previously used by some one else or in some other country.

It would appear to us, however, from a brief study of the manuscripts from an engineering standpoint, that so many of the sketches contain detailed calculations of weights, power required, costs, etc., and so many others contain practical hints, which are really shop instructions for construction and operation, that they could not have been the result of mere observation of apparatus constructed by others, but must have been the result of practical experiment and experience with actual apparatus under working conditions, supporting the contention that a large part of the sketches are original designs and represent machines, apparatus and structures actually carried out by him or under his immediate direction.

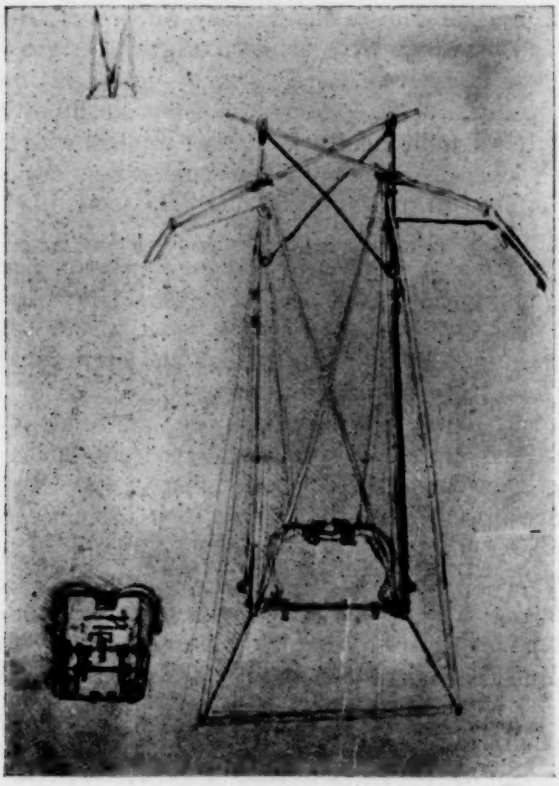
We must also recognize in Leonardo the real founder of scientific prose writing in Italian, his composition being based on the constant and well-defined use of words and terms, casting aside the involved redundant and pedantic style affected by many of his contemporaries.

The speaker has perhaps exceeded proper limits in the insertion of extended quotations, but it was felt that the best insight into Leonardo's personality and mental processes could perhaps be obtained by giving actual quotations from his notes translated as literally as possible.

While many of these notes have been translated directly from the facsimile manuscripts, for many others and for quotations and translations the speaker is indebted to the classical work of Dr.

J. P. Richter and also to the works of Baratta, Beltrami, Beck, De Toni, Duhem, Favaro, Feldhaus, Grothe, Herzfeld, Libri, Müntz, Ronna, Seailles, Seidlitz, Solmi, Venturi, Uzielli, and other foreign authorities, Klebs and Sarton, from this country, and to that excellent work by Edward McCurdy, entitled: "The Note Books of Leonardo da Vinci."

It has not been possible, in the necessarily condensed form of



Flying machine, true aeroplane, motor operated.

this address, to more than give a very general outline, a mere sketch, of the immense field of thought, of research, and of constructive detail over which the activities of this extraordinary genius extended, involving, as it does, Natural Philosophy, Literature, Physics, Mathematics, Geometry, Geology, Botany, Chemistry, Biology, Anatomy and Physiology, the Plastic and Graphic

Arts, Civil, Military, Mechanical and Hydraulic Engineering, and last, but not least of all, Aviation.

I venture the hope, however, that I may have succeeded in exciting your interest and awakening your desire to learn more of Leonardo's work, and I should feel quite happy if I could succeed in reclaiming for this wonderful man, in your estimation, his rightful place in the pantheon of the world's greatest men, not only as a great artist and painter, but as a greater Natural Philosopher and Engineer!

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(Prepared by J. W. L.)

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		Abbreviations.
Library of the Institute de France	Paris	A to M. Ash I-II.
Ambrosian Library	Milan	Codice Atlantico—C.A.
South Kensington Museum, Forster Library	London	S.K.M.—I_1, I_2, II_1, II_2 III.
British Museum	London	B.M.
Royal Library, Windsor Castle	Windsor	W.A. I-IV. W.P., W.M., W.L., W.H., W.
Holkham Hall, Library of Lord Leicester		Leic.
Library of Prince Trivulzio	Milan	Tr.
Museum of Uffizi	Florence	F.U.
Academy	Venice	V.
Royal Library	Turin	Trn. or Mz.

and miscellaneous scattered sheets.

ORIGINAL ABSTRACTS GROUPED INTO TREATISES OR SUBJECTS.

Trattato della Pittura.
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THERMAL, ELECTRICAL AND MAGNETIC PROPERTIES OF ALLOYS.*

BY

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INTRODUCTION.

THE physical properties of alloys including hardness, conductivity for heat and electricity, thermoelectric power, magnetic susceptibility, rate of change of resistance with the temperature, etc., are intimately connected with the constitution of the alloys. In the absence of intermetallic compounds the physical properties are in general continuous functions of the composition for any given series of alloys. The physical property may be a linear function of the concentration as is ordinarily the case in conglomerates or it may pass through a maximum or a minimum as in alloys formed of metals which are mutually soluble in each other in all proportions. Discontinuities may occur in cases of limited solubility in the solid state and the curve which represents the variation of the physical property with the composition then shows an abrupt change in direction at the concentration at which one metal ceases to be soluble in the other. In case the metals entering into the alloys form one or more intermetallic compounds the alloys will have a new set of physical properties at the point at which the concentration of the compound is a maximum.

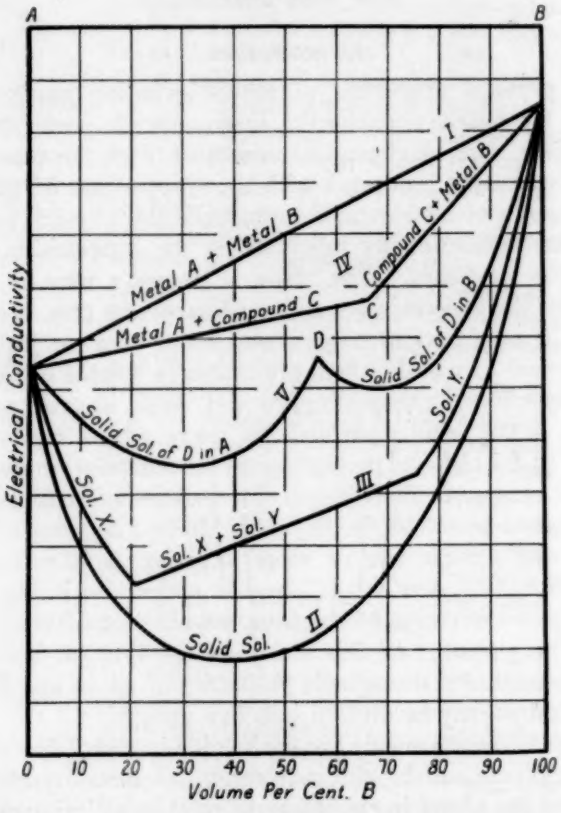
For the purposes of this study of the relation between the thermal, electrical and magnetic properties of alloys and their constitution alloys may be divided into five groups.

I. The two components are not soluble in each other and form no chemical compounds with each other. A metallographic study shows that the alloys in this case are mechanical mixtures of the two components. The lead-cadmium series is an example of this type of alloys. In such alloys the physical property is usually a linear function of the concentration of one of the components. For example, the electrical conductivity of a series of such conglomerates is represented by Curve I of Fig. 1.

* Communicated by the Author.

II. The two components are soluble in each other in all proportions, *i.e.*, they form by varying the concentration of one of the components an unbroken series of mixed crystals. Alloys of palladium with silver or nickel with copper belong to this group. A curve representing the physical property as a function of the con-

FIG. 1.



centration of one of the components is characterized by a pronounced maximum or minimum. The electrical conductivity when plotted as a function of the concentration of one of the components gives in this case a curve of the form of Curve II of Fig. 1.

III. Each of the components is soluble in the other to a lim-

ited extent. The alloys of this series will then consist of three parts, solid solutions of the first component in the second, solid solutions of the second component in the first and mechanical mixtures of saturated solutions of the first component in the second with saturated solutions of the second component in the first. A typical curve for such a property as the electrical conductivity of alloys of this group is represented in Curve III of Fig. 1. It consists of three parts, a central portion which is linear where there is a mechanical mixture of one saturated solution in another and on either side of this a portion which is similar to the initial and final parts of Curve II.

IV. The two metals *A* and *B* form a single compound *C* (Curve IV, Fig. 1) and this compound forms mechanical mixtures both with *A* and *B*. The curve representing the physical property consists of two straight lines intersecting at *C*.

V. The components form one or more intermetallic compounds. Bismuth-tellurium alloys furnish an example of this group. In this case the curves, showing the physical properties as a function of the concentration of one of the components, may assume a variety of forms according to the nature of the intermetallic compound. If the compound happens to form solid solutions with both of the components in the alloys the curve will take the form of Curve V of Fig. 1. In that case a compound *D* was formed which formed solid solutions with both *A* and *B*.

PHYSICAL QUANTITIES AND UNITS.

The specific resistance has been taken to mean the resistance in ohms or in microöhms of a wire one centimetre in cross section and one centimetre in length. The electrical conductivity is understood to be the reciprocal of the specific resistance, and it has been expressed as the reciprocal of ohms for which the term mho has been used.

The temperature coefficient of the resistance has been considered to be the rate of change of the resistance per ohm per degree Centigrade.

By the thermal conductivity is understood the quantity of heat in calories which will flow in one second through an area of one square centimetre when the temperature gradient is one degree Centigrade per centimetre.

The thermoelectric power has been measured against lead except in a few cases where it has been measured against platinum. These exceptions are clearly indicated on the figures. The thermoelectric power has been expressed as the number of microvolts for a difference of one degree Centigrade between the junctions. For the rate of variation of the thermoelectric power with the temperature the Centigrade scale has also been used.

The Thomson coefficient, which is a measure of the heat absorbed or evolved in excess of the Joulean heat by a current of electricity flowing along an unequally heated conductor, has been measured in ergs. It gives the amount of heat in ergs which is absorbed or generated in excess of Joulean heat by a current of one absolute unit flowing through a conductor in which there is a temperature gradient of one degree Centigrade per centimetre.

In the Hall constant which is a measure of the rotation of the equipotential lines under the action of a transverse magnetic field, the electric current, the transverse difference of potential and the magnetic field have been measured in absolute units and the thickness of the plate in centimetres. This constant is defined by the equation,

$$E = R\frac{Hi}{d}$$

where E = the transverse electromotive force produced by the magnetic action.

H = the intensity of the magnetic field.
i = the current in the plate.
d = the thickness of the plate.
R = the Hall constant.

For paramagnetic and diamagnetic substances the relation between the intensity of magnetization and the magnetic field which produces it may be expressed by the equation,

$$I = kH.$$

where H = the magnetic field in gausses.
k = the magnetic susceptibility per unit volume.

Sometimes the magnetic susceptibility per unit mass is used. In such a case it is called the specific magnetic susceptibility and is defined by the relation,

$$\chi = \frac{k}{\rho},$$

where ρ = density of the substitute.

To get a measure of the elastic properties of the alloys it has been necessary to accept the data on these properties in a variety of forms. In some cases the hardness on Brinell's scale has been used; in others the pressure necessary to cause the metal or alloy to flow, and in others the tensible strength. There is no simple way of passing from one of these kinds of data to the other. They all give some measure of the cohesive forces with which the metals and alloys are held together, and that was all that was needed in this connection.

Above the freezing point curve an attempt has been made to indicate the manner in which the metals mix to form the alloys (see Guertler, "Metallographie"). Where the alloys are mechanical mixtures for all concentrations of the constituents, this fact has been indicated by placing a plus sign between the chemical symbols of the constituents. For example $Zn + Sn$ means that tin and zinc are mechanical mixtures in all proportions. In case the metals A and B form an unbroken series of solid solutions, this has been indicated by writing $Sol\text{–}A\text{–}B$ above the freezing point curve. If one metal A is soluble to a limited extent in the other $B - a$ saturated solid solution of A in B has been denoted by I and a saturated solid solution of B in A by II. Where these saturated solid solutions then mix mechanically to form the remainder of the alloys, this fact has been indicated by $I + II$. For example in the case of the copper-silver series, the numerals above the freezing point curve indicated that copper dissolves about 3 per cent. silver, and that silver dissolves about 5 per cent. copper. These saturated solid solutions then mix mechanically to form the remainder of the alloys.

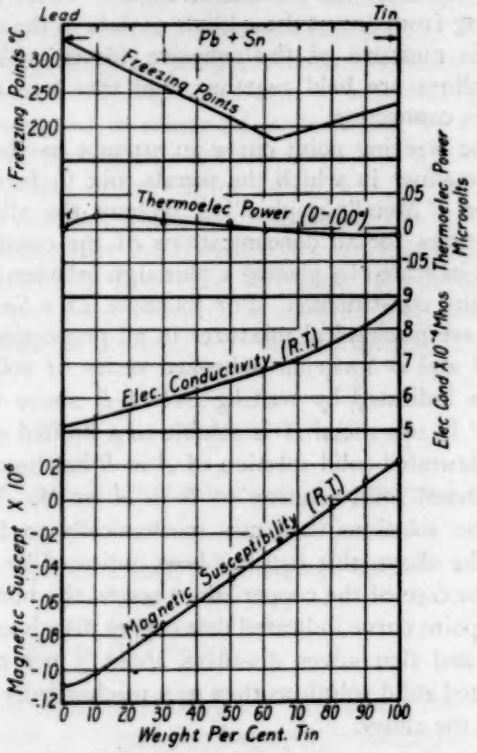
The temperature at which the observations were made or the interval of temperature over which they were made has been given on the curves as far as possible. In a number of cases the temperatures at which the observations were made were not clearly given by the observer. This is especially true for observations made in the neighborhood of room temperature. Where the observations were made near room temperature the letters ($R.T.$) have been written on the curves to indicate that fact.

METALS INSOLUBLE IN EACH OTHER.

Lead-Tin.

The freezing point curve by Degens [1] (Fig. 2) for lead-tin alloys shows a eutectic but no evidence of compounds. Tin seems to be somewhat soluble in lead and possibly lead is to a small

FIG. 2.



degree soluble in tin. Between low and high concentrations of tin the alloys are heterogeneous mixtures of the crystalline phases.

The electrical conductivities as measured by Roberts [2] give nearly a straight line as is to be expected from the fact that the alloys are heterogeneous mixtures of the components. The thermo-

[1] Degens: *Zeit. anorg. Chem.*, 63, 207, 1909.
[2] Roberts: *Phil. Mag.* (5), 8, 57, 1879.

electric powers have been determined by Rudolfi [3] and his results plotted in Fig. 2. The diamagnetic susceptibility by Honda [4] gives a curve which is nearly a straight line beginning with the value in lead and ending with the value in tin. In the alloys rich in lead (between 0 and 10 per cent. tin) where a solid solution is formed, the susceptibility decreases somewhat less rapidly than the linear relation requires. The linear relation between susceptibility and concentration follows at once from the fact that except for low and possibly high concentrations of tin the alloys are mechanical mixtures of the components.

Tin-Zinc.

The two branches of the freezing point curve (Fig. 3) by Heycock and Neville [5] meet at the eutectic. The changes in curvature are all gradual and there is no evidence of compounds. The alloys consist of heterogeneous mixtures of tin and zinc.

Measurements of the electrical conductivity have been made by Matthiessen,[6] Vogt,[7] Harris and Le Chatelier.[8] More recently Schulze [9] has studied both the thermal and the electrical conductivities. His observations have been plotted in Fig. 3. The temperature coefficient is from the work of Matthiessen and Vogt. Besides the observations of Rudolfi [3] on the thermoelectric heights there are earlier observations by Rollmann and Battelli.[10] The observations of Rudolfi have been used for the curve of thermoelective forces. Except for minor variations these curves are essentially linear and typical of alloys which are formed by mechanically mixing the constituents.

Bismuth-Cadmium.

The freezing point curve (Fig. 4) by Stoffel [11] is composed of two branches meeting at the eutectic for which the temperature

[3] Rudolfi: *Zeit. anorg. Chem.*, **67**, 65, 1910.
[4] Honda: *Sci. Rept. Tokio Univ.*, **2**, 11, 1913.
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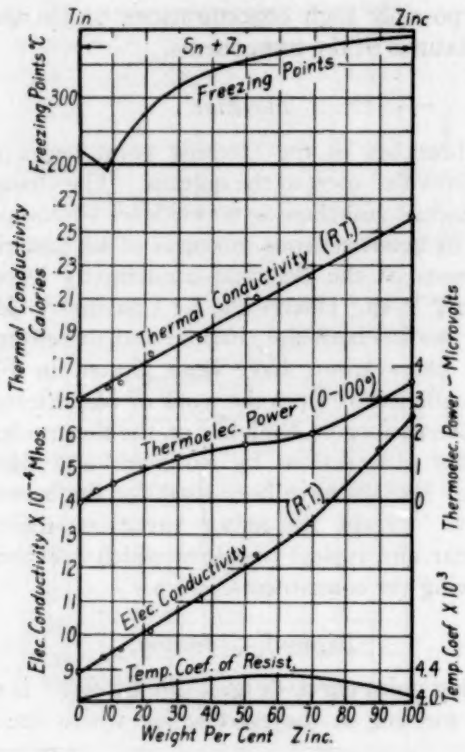
is 148° C. In all proportions the alloys are heterogeneous mixtures of bismuth and cadmium.

The thermoelectric powers by Rudolfi [12] and the magnetic susceptibility by Guesatto and Binghinnoto [13] give curves which have the form to be expected in heterogeneous mixtures. Each of these curves by their steepness where the concentration of bismuth is

FIG. 3.



large suggests that cadmium is to a limited extent soluble in bismuth. There is some evidence from the study of the homogeneity of these alloys that cadmium may be soluble in bismuth up to about 1 per cent.

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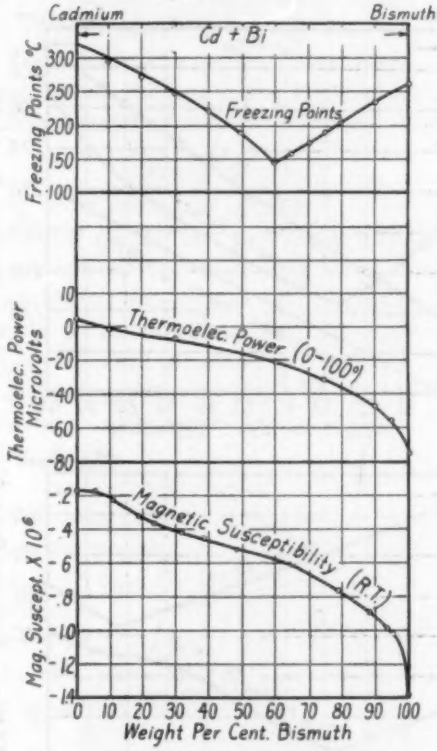
[12] Rudolfi: *Zeit. anorg. Chem.*, 67, 65, 1910.

[13] Guesatto and Binghinnoto: *Inst. Ven.*, 69, 1382.

Cadmium-Tin.

The equilibrium diagram by Lorentz and Plumbridge [14] shows that the freezing point curve (Fig. 5) consists of two branches meeting at a eutectic when the alloy contains about 28 per cent. cadmium. These alloys are heterogeneous mixtures in all proportions.

FIG. 4.



The electrical conductivity curve by Matthiessen and Vogt [15] is a straight line. The curve giving the thermoelectric power as a function of the concentration is also a straight line. Besides these observations by Rudolfi [12] there are some earlier observations by Battelli.[16] Both of these curves are characteristic of alloys formed by mechanical mixtures of the constituents. Concerning the other

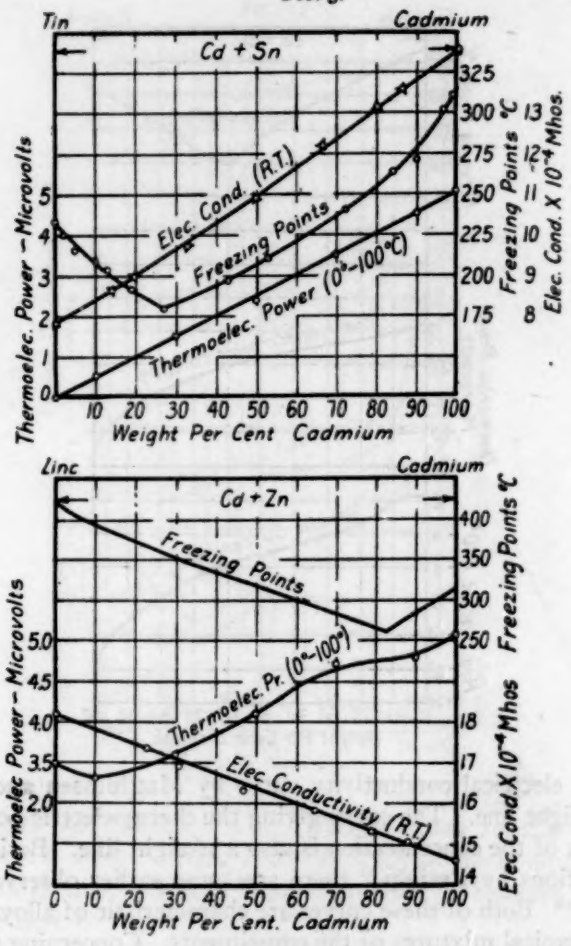
[14] Lorentz and Plumbridge: *Zeit. anorg. Chem.*, **83**, 237, 1913.
[15] Matthessien: *Pogg. Ann.*, **110**, 206, 1860.
[16] Battelli: *Mem. di Torino* (2), **36**, 31, 1884.

thermal, electrical and magnetic properties of these alloys, no observations seem to be available.

Cadmium-Zinc.

The freezing point curve for cadmium-zinc alloys by Lorentz and Plumbridge [17] (Fig. 5) consists of two branches meeting at the

FIG. 5.



eutectic for which the temperature is 270° C. The alloys are mechanical mixtures of zinc and cadmium.

[17] Lorentz and Plumbridge: *Zeit. anorg. Chem.*, 83, 236, 1913.

The electrical conductivities at room temperature have been measured by Matthiessen [18] and also by Vincentini. The curve showing the electrical conductivity as a function of the concentration of one of the constituents come out to be a straight line, as it should for this type of alloys. Battelli [19] has made a study of the thermoelectromotive forces of these alloys and a later investigation was made by Rudolfi.[20] The average values of the thermoelectric powers as determined by Rudolfi have been plotted on the curve in Fig. 5. This curve departs somewhat from a straight line and suggests by its minimum for low concentrations of cadmium that cadmium may be soluble to a limited extent in zinc.

Aluminium-Tin.

The freezing point curves of Gautier [21] and Gwyer [22] for this series of alloys differ by the fact that the freezing point curve of Gautier has a maximum corresponding to the compound AlSn and the curve by Gwyer shows no such maximum. The curve by Gwyer seems to be preferred and it has been reproduced in Fig. 6. According to Gwyer, there seems to be a eutectic which coincides nearly with the melting point of tin. Except for the possibility of slight solubility in each other these metals form alloys which are mechanical mixtures.

Besides the observations of Broniewski [23] on the electrical properties of these alloys there are available some observations by Pecheux on their thermoelectromotive force. The data given by Broniewski have been used for the curves plotted in Fig. 6. These curves in agreement with the freezing point curve lead to the conclusion that these metals do not form definite compounds and are characterized by dilute solid solution of tin in aluminium and a mixture of this solution with tin.

Aluminium-Bismuth.

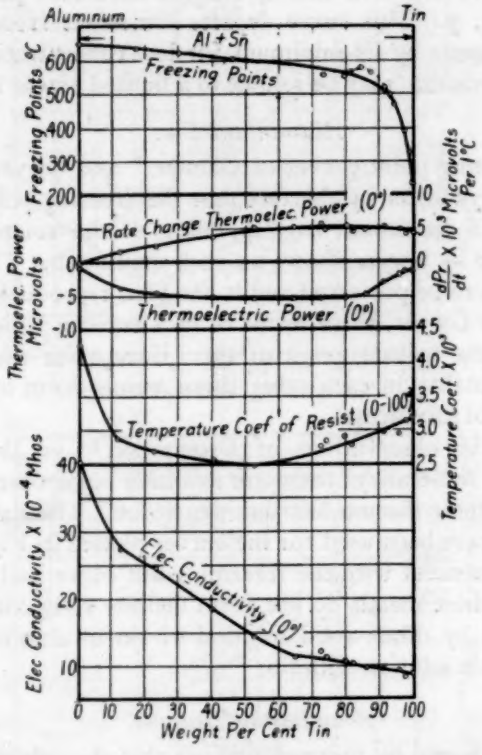
Gwyer [24] found by thermal analysis that the solubility of aluminium in bismuth is about 2 per cent. and that of bismuth in

[18] Matthiessen: *Pogg. Ann.*, 110, 28, 1860.
[19] Battelli: *Atti. R. Inst. Veneto* (6) 5, 1148, 1886.
[20] Rudolfi: *Zeit. anorg. Chem.*, 67, 65, 1910.
[21] Gautier: *C. R.*, 123, 109, 1896.
[22] Gwyer: *Zeit. anorg. Chem.*, 49, 315, 1906.
[23] Broniewski: *Ann. de Phys. et Chem.* (8), 25, 63, 1912.
[24] Gwyer: *Zeit. anorg. Chem.*, 49, 316, 1906.

aluminium is about 4 per cent. at 650° C., but inappreciable at the melting point of bismuth. The alloys may, therefore, be regarded as mechanical mixtures of aluminium and bismuth. The freezing point curve of Fig. 7 is by Gwyer.

Some work has been done by Pecheux [25] on the thermoelectromotive forces in these alloys. They were more fully studied by

FIG. 6.

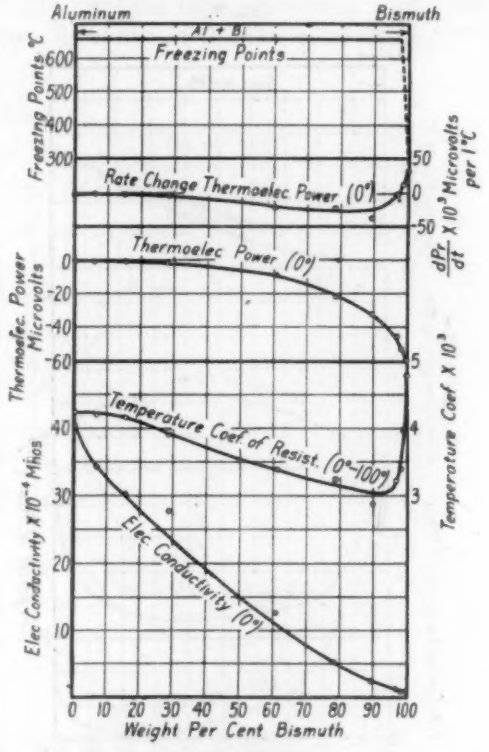


Broniewski [26] from whose observations the curves in Fig. 7 have been taken. Except for a slight minimum where the concentration of aluminium is small the curve for electrical conductivities is nearly a straight line, as it should be for alloys formed by metals which are mechanically mixed. The curve for the temperature

[25] Pecheux: *C. R.*, 138, 1501, 1904.
[26] Broniewski: *Ann. de Phys. et Chem.* (8), 25, 66, 1912.

coefficient of the resistance has a minimum at about 95 per cent. bismuth. This together with the slight minimum in the electrical conductivity curve indicates the formation of a solid solution of aluminium in bismuth. Since these minima are more pronounced

FIG. 7.



in the unannealed than in the annealed specimens the solid solution is probably decomposed by annealing.

METALS COMPLETELY SOLUBLE IN EACH OTHER.

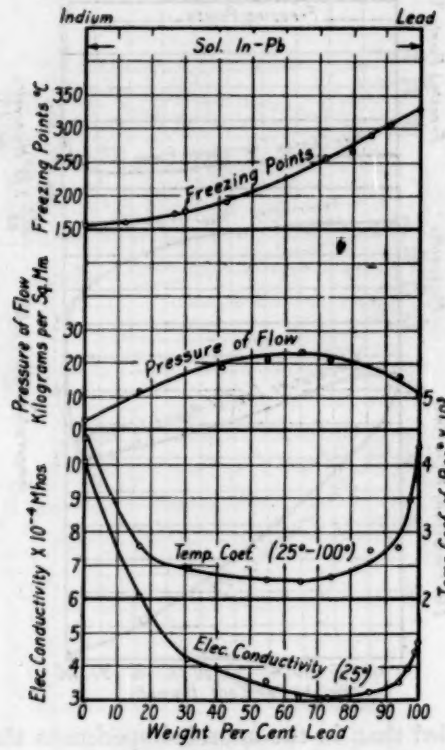
Indium-Lead.

Lead and indium form an isomorphous mixture in all proportions. The freezing point curve (Fig. 8) by Kurnakow and Puschin [27] is a continuous curve through the melting points of lead and indium.

[27] Kurnakow and Puschin: *Zeit. anorg. Chem.*, 52, 430, 1907.

The electrical conductivity and the temperature coefficient have been measured by Kurnakow and Zemczuzny.[28] These authors have also determined the pressure necessary to cause these alloys to flow. All of the curves representing these physical quantities as

FIG. 8.



functions of the concentration are typical of alloys in which the constituents form a continuous series of mixed crystals. The pressure necessary to produce flow has a maximum value where the electrical conductivity and the temperature coefficient of the resistance have minimum values. This indicates that the electrical properties are in part at least determined by the elastic properties.

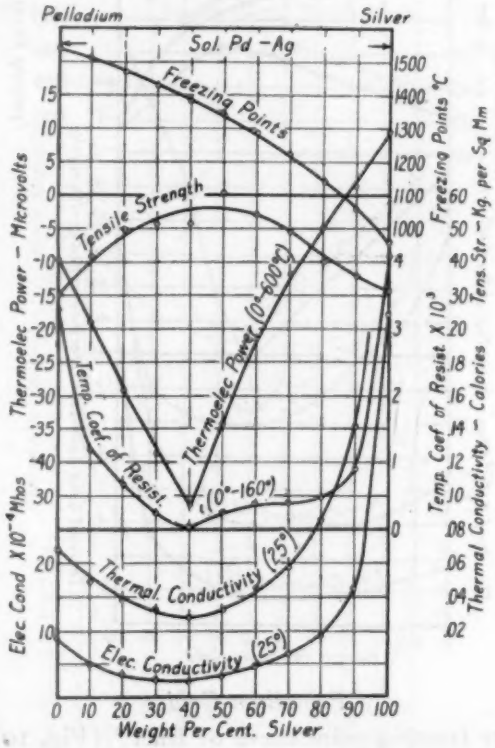
[28] Kurnakow and Zemczuzny: *Zeit. anorg. Chem.*, **64**, 149, 1909.

Palladium-Silver.

The freezing point curve of these alloys (Fig. 9) is plotted from the data of Ruer.[29] The metals form solid solutions in all proportions.

The electrical and thermal conductivities have been determined by Schulze.[30] He used the same specimens which had been used by Giebel [31] for the study of the electrical conductivity, the tem-

FIG. 9.

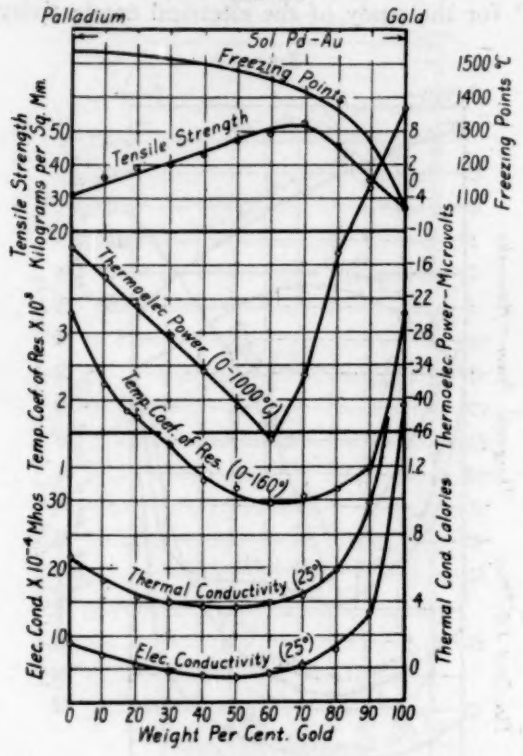


perature coefficient of the resistance, the thermoelectric heights and the tensile strength. All of these curves except possibly the one for thermoelectric heights are characteristic of metals which

[29] Ruer: *Zeit. anorg. Chem.*, 51, 315, 1906.
[30] Schulze: *Physikal Zeitschr.*, 12, 1029, 1911.
[31] Giebel: *Zeit. anorg. Chem.*, 70, 240, 1911.

form a continuous series of mixed crystals. The elastic properties as represented by the tensible strength of these alloys have a maximum where the electrical conductivity, the thermal conductivity, the thermoelectric power and the temperature coefficient of the resistance have minimum values.

FIG. 10.



Palladium-Gold.

From the freezing point curve of Ruer [2] (Fig. 10) it is seen that the freezing point of these alloys changes gradually from the melting point of palladium to the melting point of gold. The metals form an unbroken series of mixed crystals.

The electrical and thermal conductivities have been measured by Schulze [3] and the thermoelectric powers, the temperature coefficient and the tensile strengths by Giebel [32] who also measured the

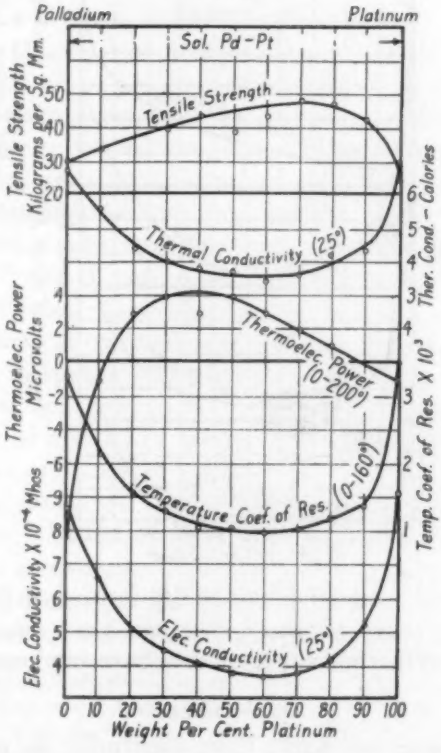
[32] Giebel: *Zeit. anorg. Chem.*, 70, 240, 1911.

electrical conductivity. All of these observations were made on the same specimens. These curves are all very similar to the corresponding curves for palladium-silver alloys and typical of alloys in which there is an unbroken series of mixed crystals. Here as in other similar cases the elastic properties are related to the electrical and thermal properties.

Palladium-Platinum.

The freezing point curve for this series of alloys does not seem to have been studied. The physical properties (Fig. 11) clearly

FIG. 11.

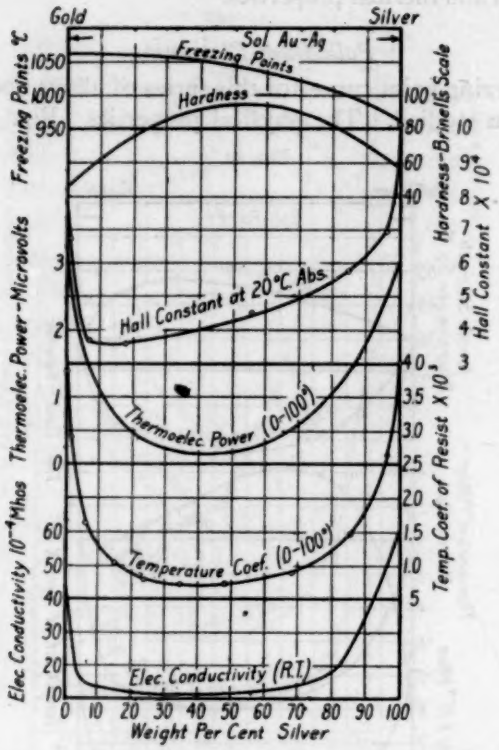


indicate that these metals mix in all proportions forming a continuous series of mixed crystals.

The thermal and electrical conductivities which have been given in Fig. 11 have been taken from the work of Schulze who made

his observations on the same specimens on which Giebel [32] had made observations on the electrical conductivity, the temperature coefficient of the resistance, the thermoelectric power and the tensile strength. There is an evident parallelism between the elec-

FIG. 12.



trical and thermal conductivities. In this series as in the palladium-silver series the curve of tensile strengths has a maximum where the electrical and thermal conductivities have minimum values.

Gold-Silver.

Roberts-Austen and Kirke Rose, confirming the work of Heycock and Neville,[33] showed that gold and silver solidify in the form of an unbroken series of mixed crystals. The freezing point changes continuously from its value in gold to its value in silver.

[32] Heycock and Neville: *Phil. Trans. A.*, 189, A, 69, 1897.

The curve for the electrical conductivities (Fig. 12) is plotted from the observations of Matthiessen.[34] The average thermoelectric power has been calculated from the data of Rudolfi [35] and the Hall constant from the work of Beckman.[36] The hardness has been measured by Kurnakow.[37] The similarity between the four lower curves in Fig. 12 is very evident. The elastic property has a maximum value where the other properties have minimum values, indicating that the elastic forces in the alloys help to determine the Hall effect as well as the electrical conductivity, the temperature coefficient of the resistance and the thermoelectric powers.

Copper-Gold.

From the observations of Kurnakow and Zemczuzny [38] on the freezing points of copper-gold alloys (Fig. 13) it is found that the freezing point curve runs in a simple way from the melting point of copper to the melting point of gold. It has a minimum where the alloy contains about 25 per cent. copper. These metals form a continuous series of solid solutions.

The electrical conductivity of this series has been studied by Matthiessen [39] and in later times by Kurnakow, Zemczuzny and Zasedatelev [40] from whose observations have been taken both the curve for electrical conductivities and the curve for temperature coefficient of resistance. The hardness which has been measured by Kurnakow and Zemczuzny [41] shows the maximum which is characteristic of a series of solid solutions. The average thermoelectric power as found by Rudolfi [1] has been used for the thermoelectric height curve. Except for the two peaks in the curve for the electrical conductivity and two corresponding peaks in the curve for the temperature coefficient of the resistance, this set of curves is very similar to the set found for alloys of platinum and palladium in which there was a continuous series of solid solutions.

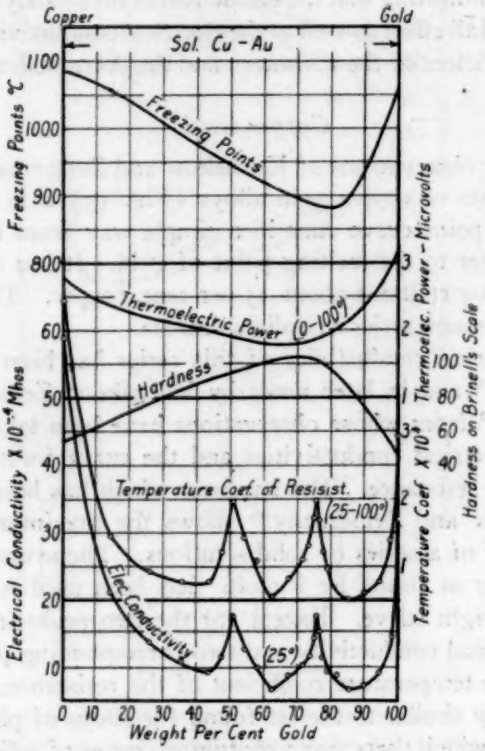
[34] Matthiessen: *Pogg. Ann.*, 110, 190, 1861.
[35] Rudolfi: *Zeit. anorg. Chem.*, 67, 65, 1910.
[36] Beckman: *Com. fr. Phys. Lab. Univ. of Leiden*, 130, 27, 1912.
[37] Kurnakow: *Zeit. anorg. Chem.*, 60, 1, 1908.
[38] Kurnakow and Zemczuzny: *Zeit. anorg. Chem.*, 54, 163, 1907.
[39] Matthiessen: *Pogg. Ann.*, 110, 217, 1860.
[40] Kurnakow, Zemczuzny and Zasedatelev: *J. Inst. of Metals*, 15, 305, 1916.
[41] Kurnakow and Zemczuzny: *Zeit. anorg. Chem.*, 60, 1, 1908.

Potassium-Rubidium.

These metals form isomorphous mixtures in all proportions. The freezing point curve has not been located and it seems to be unknown.

The observations on the electrical conductivity and on the rate of change of the resistance with the temperature (Fig. 14) are

FIG. 13.

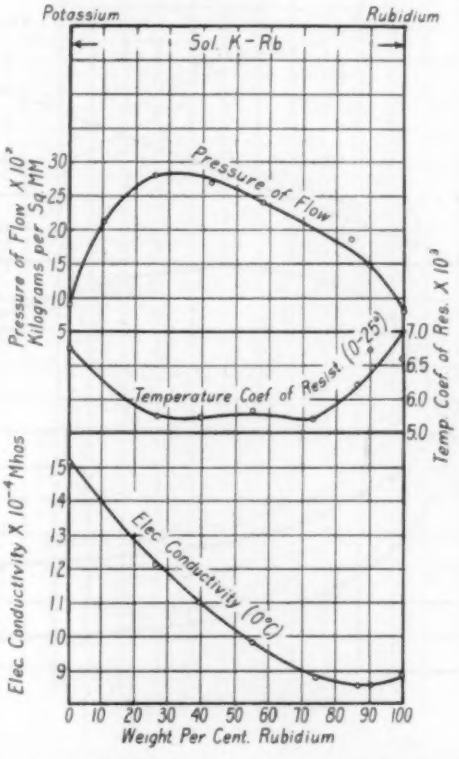


due to Kurnakow and Nikitinsky.[42] They also determined the pressures required to cause the alloys to flow. The electrical conductivity as a function of the concentration of one of the components is represented by a continuous curve with a very slight minimum. This is characteristic of isomorphous mixtures. With rising temperature the minimum is displaced toward rubidium—

[42] Kurnakow and Nikitinsky: *Zeit. anorg. Chem.*, **88**, 151, 1914.

the metal with the least conductivity. The curve for the rate of change of the resistance with the temperature shows the minimum characteristic of this type of alloys. The only difference between these curves and those obtained under similar conditions for most isomorphous mixtures is the smaller decrease in the electrical conductivity which is produced by adding rubidium to potassium. In most cases in which solid solutions are formed this decrease is

FIG. 14.



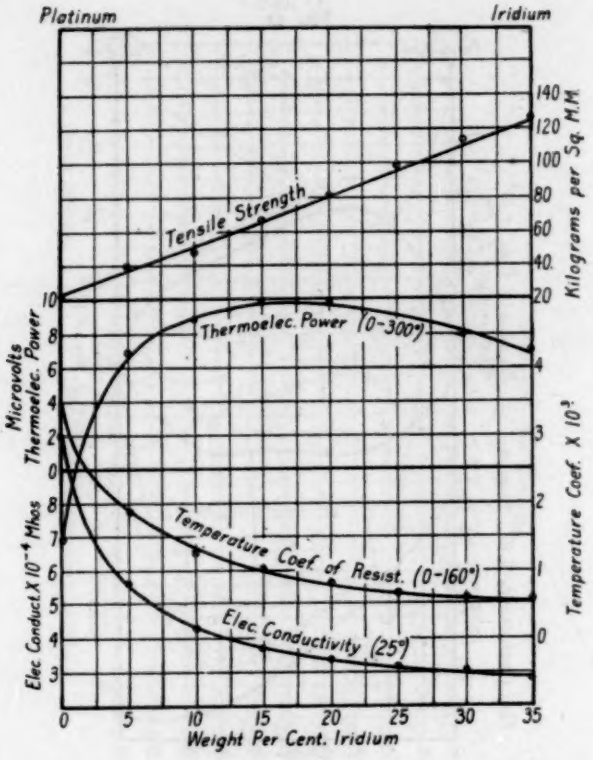
much larger than it is in this case. The elastic properties as measured by the pressure necessary to cause the alloys to flow show the characteristic maximum found in isomorphous mixtures.

Platinum-Iridium.

The equilibrium diagram for this series has not been located. These metals probably form solid solutions.

The electrical conductivity, the temperature coefficient, the thermoelectric power, and the tensile strength have been studied by Giebel [43] for this series of alloys for concentrations of iridium between 0 and 35 per cent. These curves are reproduced in Fig. 15. The tensile strength is a linear function of the concen-

FIG. 15.



tration of iridium over this interval. The thermoelectric power passes through a maximum between 15 and 20 per cent. iridium. The addition of iridium to platinum lowers both the electrical conductivity and the temperature coefficient in the way to be expected on the assumption that the metals form solid solutions.

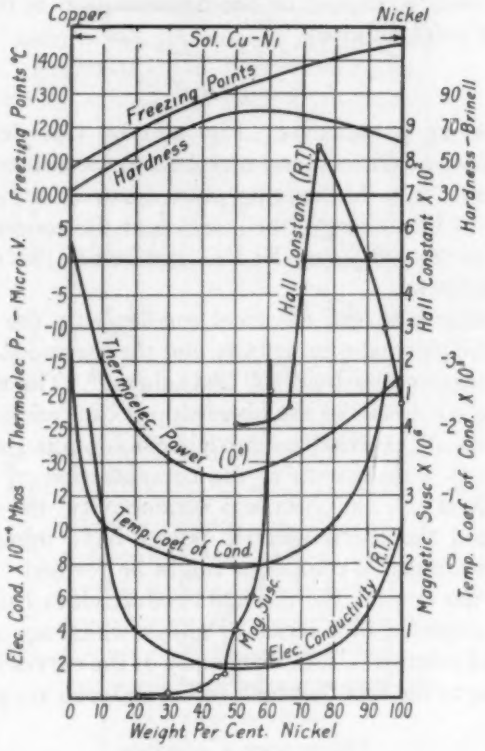
[43] Giebel: *Zeit. anorg. Chem.*, 70, 247, 1911.

Copper-Nickel.

The freezing point curve for this series of alloys (Fig. 16) is the one worked out by Guertler and Tammann.[44] These metals form an unbroken series of solid solutions.

The electrical conductivity and the temperature coefficient have

FIG. 16.



been measured by Feussner.[45] The curves thus obtained are characteristic of a continuous series of solid solutions. The thermoelectric power by Englisch [46] and the hardness by Kurnakow and Papke [47] also give the type of curve to be expected in alloys which

[44] Guertler and Tammann: *Zeit. anorg. Chem.*, **53**, 281, 1907.
[45] Feussner: *Verhand. d. physik Gesel. zu Berlin*, **10**, 109, 1891.
[46] Englisch: *Phys. Consts. Soc. Fran. de Phys.*, p. 654, 1893.
[47] Kurnakow and Papke: *Zeit. anorg. Chem.*, **87**, 274, 1914.

are solid solutions. The curve of hardness shows a maximum where the curve for the electrical conductivity has a minimum, thus showing that the elastic properties in a measure determine the electrical conductivity and its variation with the temperature. The curve for the magnetic susceptibilities has been taken from the observations of Gans and Fouseca.[48] The Hall constant is by the author.[49] Neither the Hall constants nor the magnetic susceptibilities seem to depend on the concentration in the way to be expected for solid solutions.

Iron-Nickel.

The freezing point curve (Fig. 17) by Guertler and Tammann [50] indicates that iron and nickel form a continuous series of solid solutions. On the freezing point curve as sometimes given there seems to be a change in curvature at the concentration corresponding to the compound Ni_2Fe, from which this compound is sometimes inferred.

The specific heat, the electrical conductivity, the temperature coefficient, the thermal conductivity and the thermoelectric heights have been measured by Ingersoll and others.[51] The flux densities given in Fig. 17 are from the observations of Yensen [52] and were measured for an external magnetic field of 400 gausses. The specific heat is a maximum at the concentration of the possible compound Ni_2Fe. The electrical conductivity, the temperature coefficient and the thermoelectric power have minimum values where the intermetallic compound might be formed. Of all these curves only the one for the thermal conductivities has the general form to be expected in a series of alloys which are an unbroken series of solid solutions. The complexity of the curves in this case is doubtless due to the fact that both nickel and iron are polymorphic.

Magnesium-Cadmium.

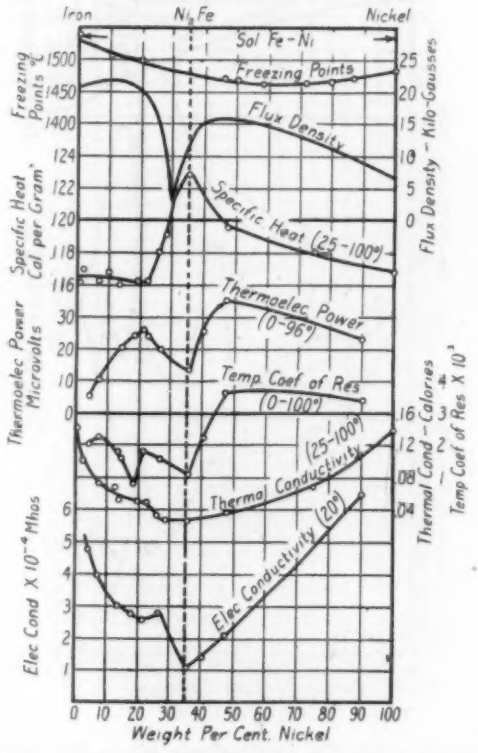
The freezing point curve by Grube [53] has a point of inflection where the concentration corresponds to the compound MgCd.

[48] Gans and Fouseca: *Ann. d. Phys.*, **61**, 742, 1920.
[49] Smith: *Phys. Rev., N. S.*, **17**, 24, 1921.
[50] Guertler and Tammann: *Zeit. anorg. Chem.*, **45**, 205, 1905.
[51] Ingersoll: *Phys. Rev., N. S.*, **16**, 85, 1920.
[52] Yensen: *Jour. A. I. E. E.*, **396**, 1920.
[53] Grube: *Zeit. anorg. Chem.*, **49**, 72, 1906.

This change in curvature is not very evident in the curve as plotted in Fig. 18. According to this equilibrium diagram the alloys are solid solutions of two crystalline phases. About the equilibrium in this series there is still considerable doubt.

The electrical conductivity, the temperature coefficient, and

FIG. 17.

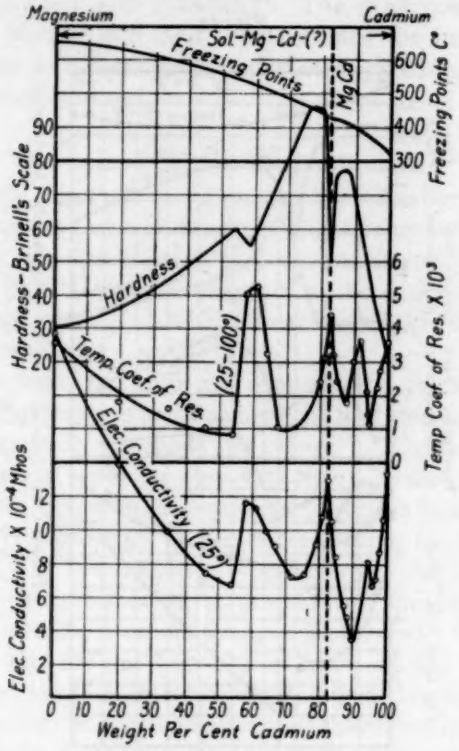


hardness have been measured by Ourazow.[54] On both of these curves the compound MgCd is clearly marked by a cusp. This compound is also indicated on the curve for hardness. On either side of the compound there is a second cusp in the curve for electrical conductivity and for the temperature coefficient. If these cusps were absent the curves would have the normal course

[54] Ourazow: *Zeit. anorg. Chem.*, **73**, 31, 1912.

to be expected on the assumption that alloys to the right of the compound are solid solutions of cadmium and the compound MgCd and those to the left of the compound solid solutions of magnesium with the compound MgCd. The thermal analysis is

FIG. 18.



not in agreement with the indications given by the thermal and electrical properties in this case.

METALS WITH LIMITED SOLUBILITY IN EACH OTHER.

Aluminium-Zinc.

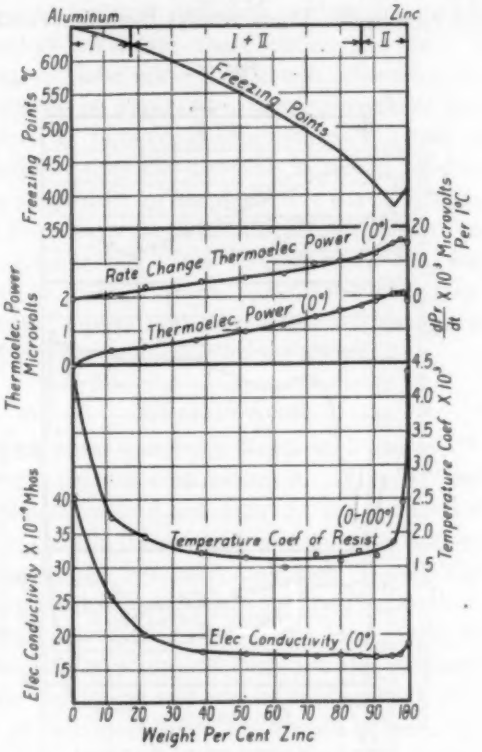
The freezing point curve of aluminium-zinc alloys from Gautier [55] (Fig. 19) is made up of two branches which meet at the temperature of fusion of the eutectic. There are no compounds

[55] Gautier: *Bull. Soc. Encour.* (5), 1, 1293, 1896.

and Shepherd [56] concludes from a micrographic study that aluminium-zinc alloys are formed of two solid solutions and a mechanical mixture of these solid solutions.

Besides the observations of Broniewski [57] on the electrical

FIG. 19.



properties of these alloys there are earlier observations by Battelli [58] and Pecheux.[59] The curves in Fig. 19 have been plotted from the observations of Broniewski. The curves all belong to that group of alloys which are formed from metals which are soluble in each other to a limited extent and in which the solid solutions

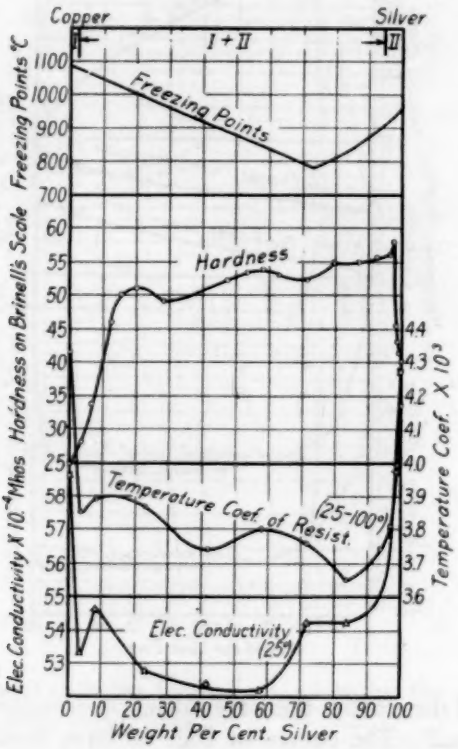
[56] Shepherd: *Jour. Phys. Chem.*, **9**, 504, 1905.
[57] Broniewski: *Ann. de Chem. et Phys.* (8), **25**, 1, 1912.
[58] Battelli: *Atti. R. Inst. Veneto.* (6), **5**, 1148, 1886–7.
[59] Pecheux: *C. R.*, **138**, 1103, 1904.

thus formed mix with each other mechanically. The central portions of the curves are nearly linear as should be the case for mechanical mixtures.

Copper-Silver.

A thermal analysis of copper-silver alloys has been made by Heycock and Neville.[60] Their results have been confirmed by the

FIG. 20.



work of Friedrick and Leroux and Lepowiski,[61] from whose work the freezing point curve (Fig. 20) is taken. Copper forms a solid solution with silver and silver with copper until the concentration of the copper in one case and silver in the other is about

[60] Heycock and Neville: *Phil. Trans. A.*, **189**, 25, 1897.
[61] Lepowiski: *Zeit. anorg. Chem.*, **59**, 289, 1908.

5 per cent. The remainder of the alloys are heterogeneous mixtures of these saturated solid solutions.

The hardness, the electrical conductivity and the temperature coefficient of this series are due to Kurnakow, Puschin and Semkowsky.[62] Where a solid solution is formed between copper and silver there is a marked lowering of both the electrical conductivity and the temperature coefficient. Hence for high as well as low concentrations of silver these curves are very steep. The central portions of these curves, although somewhat irregular, approach the form to be expected in a region where there is a mechanical mixture of two crystalline phases. There is a marked increase in hardness over the intervals in which solid solutions are formed. The remainder of the hardness curve is such as is to be found where the alloys are mechanical mixtures of two crystalline phases. Except for some irregularities this set of curves clearly belongs to metals which form solid solutions with each other to a limited extent and then these solid solutions mix mechanically to form the remainder of the alloys.

Bismuth-Lead.

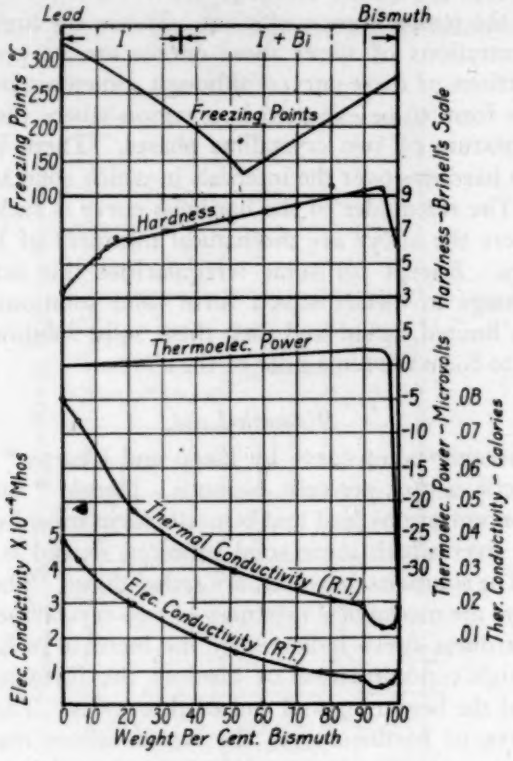
The freezing point curve by Kapp and Charpy[63] (Fig. 21) has a eutectic at 56.5 per cent. bismuth. Herold[64] finds that for suitable concentrations lead and bismuth form mixed crystals, but the region over which these solid solutions extend is not clearly defined. The solutions, however, are rather dilute. The remainder of the alloys are mechanical mixtures of two crystalline phases.

The hardness curve indicates by the increase in hardness for low and high concentrations of bismuth the formation of solid solutions at the beginning and end of this series. The remainder of the curve of hardness over the region where the alloys are heterogeneous mixtures is a straight line. The thermal and electrical conductivities by Schulze[65] have minima for alloys containing 4 or 5 per cent. of lead. This as well as the initial drops in these curves for alloys containing from 0 to 15 per cent. bismuth is further evidence for the formation of solid solutions at either end of this series. The thermoelectromotive force which

[62] Kurnakow, Puschin and Semkowsky: *J. d. russ. phys. Chem.*, **42**, 733, 1910.
[63] Barlow: *Zeit. anorg. Chem.*, **70**, 183, 1911.
[64] Herold: *Zeit. anorg. Chem.*, **112**, 131, 1920.
[65] Schulze: *Ann. d. Phys.*, **9**, 564, 1902.

has been studied by Battelli [66] shows a rapid decrease for the addition of small quantities of lead to bismuth. The characteristics of this curve in this region are similar to the characteristics of the other curves over this same region.

FIG. 21.



Antimony-Tin.

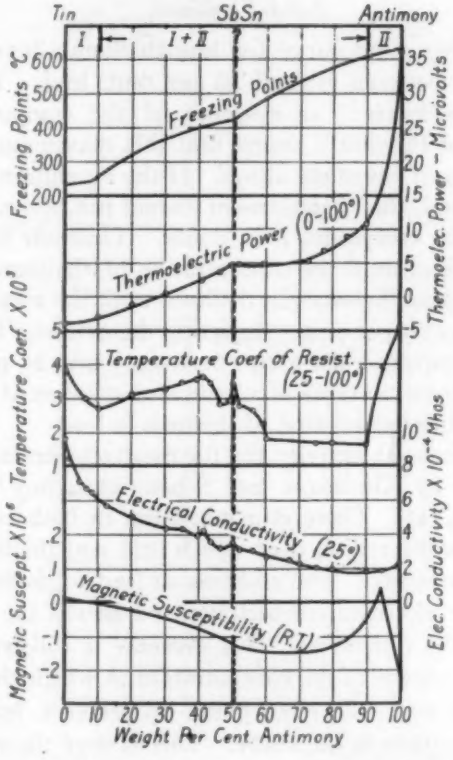
The freezing point curve by Williams [67] (Fig. 22) consists of three parts. Later study of equilibrium in this system has been made by Konstantinow and Smirnow, LeGris and Loebe. Between 90 and 100 per cent. antimony there is a solid solution of tin in antimony and between 0 and 10 per cent. tin there is a

[66] Battelli: *Atti. R. Inst. Veneto* (6), **5**, 1148, 1886.
[67] Williams: *Zeit. anorg. Chem.*, **55**, 12, 1907.

solid solution of antimony in tin. When the metals are present in equal concentrations a new crystalline phase is formed, probably the intermetallic compound SnSb. Those alloys which are not solid solutions for large and small concentrations of antimony are mechanical mixtures of two crystalline phases.

The electrical conductivity and the temperature coefficient are

FIG. 22.



by Konstantinow and Smirnow [68] and the magnetic susceptibility by Leroux.[69] The initial decrease in the electrical conductivity, the temperature coefficient of the resistance and the thermoelectric power [70] caused by the addition of tin to antimony give evidence

[68] "Annual Tables of Constants and Numerical Data," Vol. 2, p. 345.
[69] Leroux: *C. R.*, 156, 1764, 1913.
[70] Hutchins: *Jour. Am., Amer. Jour. Sci.*, 48, p. 226, 1894.

of the formation of a solid solution over this region. On the other side of the diagram where the concentration of antimony is less than 10 per cent. the curve for the electrical conductivity and for the temperature coefficient show again the presence of solid solutions. The curve for the magnetic susceptibilities indicates the compound by a change in its curvature at that concentration. The evidence for the structure of this series is not conclusive.

Lead-Thallium.

The freezing point curve for lead-thallium alloys has a very flat maximum between 30 and 40 per cent. lead. This was regarded by Lewkonja [71] as evidence of the compound $PbTh_2$. Kurnakow and Puschin [72] found that this maximum is displaced by the addition of tin to the alloys. If the maximum were due to a true compound, this displacement should not occur. Hence the existence of the compound is in doubt. Thallium forms a solid solution with lead until the concentration of thallium is about 75 per cent., and lead dissolves in thallium until the concentration of lead is about 4 or 5 per cent. Rejecting the evidence for the existence of the compound, the alloys between 5 and 25 per cent. lead are heterogeneous mixtures of a saturated solution of lead in thallium with a saturated solution of thallium in lead.

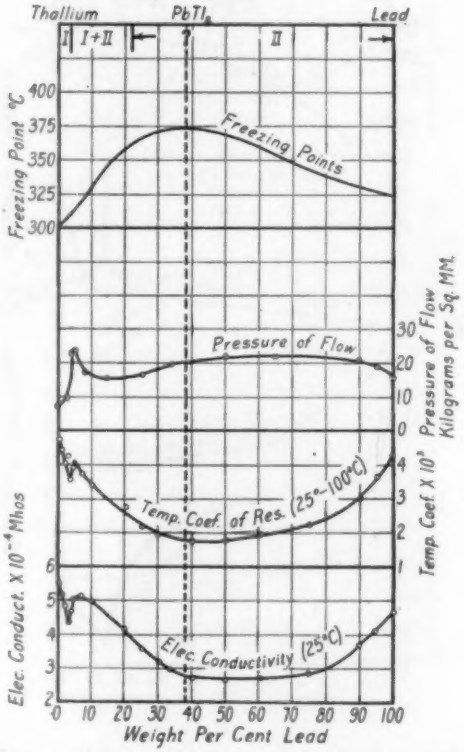
The electrical conductivity and the mean temperature coefficient as determined by Kurnakow and Schemtschuschny [73] have been plotted in Fig. 23. There is a minimum in both curves. This minimum is in the region over which lead and thallium form an isomorphous mixture. The addition of lead to thallium causes a decrease in the electrical conductivity and also in the temperature coefficient of the resistance. This decrease is followed by an increase which extends to the concentration at which the solution is saturated with lead. Between 5 and 25 per cent. lead there is a straight line portion in the curve. This is over the region where the alloys are mechanical mixtures of two crystalline phases. The pressure required to produce flow in these alloys is taken from these same observers. The curve thus obtained shows the characteristic relation between the electrical and the elastic properties.

[71] Lewkonja: *Zeit. anorg. Chem.*, **52**, 452, 1907.
[72] Kurnakow and Puschin: *Zeit. anorg. Chem.*, **52**, 430, 1907.
[73] Kurnakow and Schemtschuschny: *Zeit. anorg. Chem.*, **64**, 156, 1909.

Lead-Antimony.

The freezing point curve (Fig. 24) by Gontermann [74] shows a eutectic in the neighborhood of 13 per cent. antimony. Gontermann finds some evidence of an intermediate crystalline constituent. Aside from this possible exception these alloys may be considered mechanical mixtures.

FIG. 23.

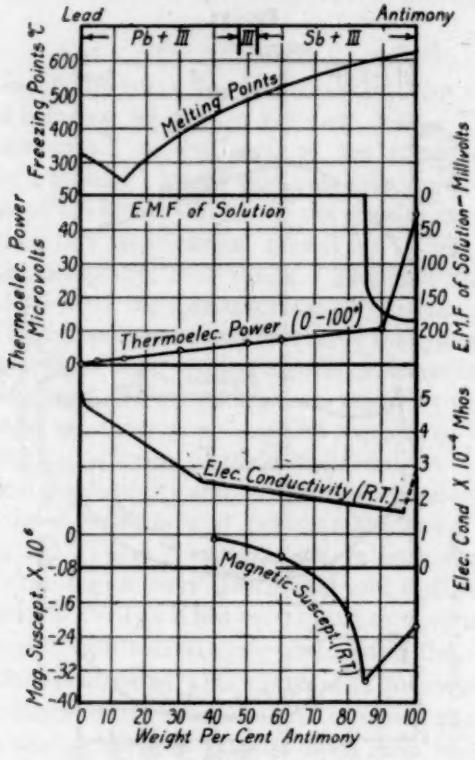


The curve for electrical conductivities is by Matthiessen; [75] for the thermoelectric powers by Rudolfi; [76] for magnetic susceptibilities by Leroux,[77] and for the electromotive force of dissolution by Pouchine. The curve for the thermoelectric powers is a straight

[74] Gontermann: *Zeit. anorg. Chem.*, **55**, 419, 1907.
[75] Matthiessen: *Pogg. Ann.*, **110**, 28, 1860.
[76] Rudolfi: *Zeit. anorg. Chem.*, **67**, 65, 1910.
[77] Leroux: *C. R.*, **156**, 1764, 1913.

line until the alloy contains 90 per cent. antimony. At that concentration the thermoelectric power rises rapidly to its value in pure antimony. At about this same concentration the curve for the magnetic susceptibilities and for the electromotive forces of solution show peculiarities. There seems to be nothing in the struc-

FIG. 24.



ture of the alloys to offer an explanation of this sudden change in the direction of the curves at this concentration.

Copper-Cobalt.

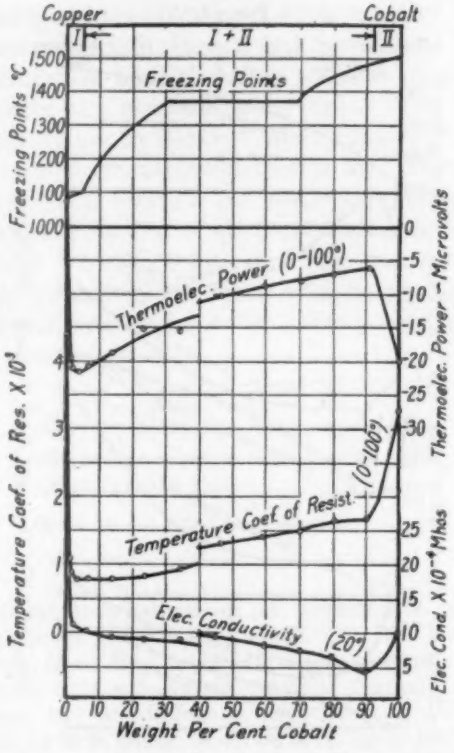
The equilibrium diagram by Sahmen [78] from which the freezing point curve (Fig. 25) is taken shows that copper and cobalt form mixed crystals with each other over a limited region. Cop-

[78] Sahmen: *Zeit. anorg. Chem.*, **57**, 1908.

per is soluble in cobalt up to 8 per cent. and cobalt in copper up to 5 per cent. cobalt. The remainder of the alloys are a heterogeneous mixture of a saturated solution of cobalt in copper and a saturated solution of copper in cobalt.

The curve for electrical conductivity, temperature coefficient and thermoelectric height are from the observations of Reichardt.[79]

FIG. 25.

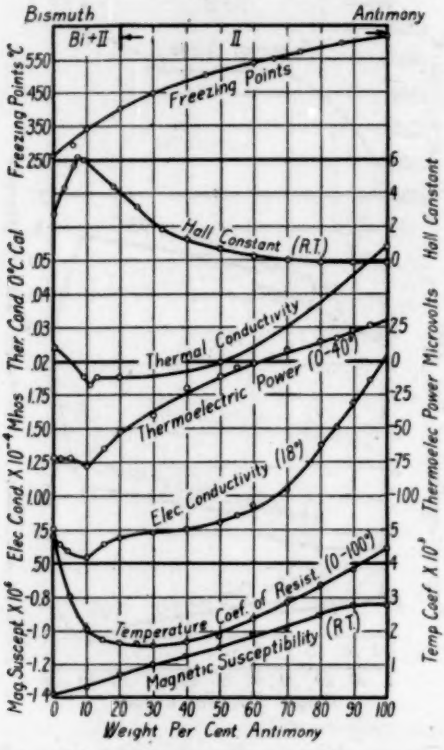


Each of these curves shows a discontinuity since alloys with less than 60 per cent. copper were so brittle that they could not be forged into wires and were investigated in the form of castings. Aside from these discontinuities the curve for electrical conductivity and the curve for temperature coefficient of resistance are typical of alloys in which the constituents are soluble in each other

[79] Reichardt: *Ann. d. Phys.*, 6, 842, 1901.

to a limited extent. The central portion of the curves are essentially linear, as they should be for alloys formed by the mixture of two crystalline phases. The curve for thermoelectric powers is peculiar in view of the fact that the addition of cobalt to copper causes a rapid decrease in the thermoelectric height and the addition of copper to cobalt causes a somewhat less rapid increase in the thermoelectric height of cobalt.

FIG. 26.



Bismuth-Antimony.

The freezing point curve (Fig. 26) by Huttner and Tammann[80] shows that the freezing points of these alloys decrease gradually from the melting point of bismuth. Concerning the structure of the alloys there seems to be some doubt. Between 18

[80] Huttner and Tammann: *Zeit. anorg. Chem.*, 44, 131, 1905.

and 100 per cent. antimony they may be considered solid solutions of bismuth and antimony and between 0 and 18 per cent. antimony they are mixtures of bismuth and a saturated solution of antimony and bismuth.

The thermoelectromotive forces of this series have been studied by Seebeck, Rollmann, Matthiessen, Becquerel, Sundell, Battelli, Hutchins and more recently by Haken [81] from whose data the curve of Fig. 26 is taken. The electrical conductivity is known from the work of Matthiessen, Calvert and Johnason and Haken.[81] The magnetic susceptibility by Honda and Sone [82] is a linear function of the concentration until the alloy contains about 90 per cent. antimony where the proportionality fails. The curve for the thermal conductivities by Gehlhoff and Neumaier [83] is very similar to the curve for electrical conductivities by Haken. This shows that Wiedmann and Franz's law holds approximately for these alloys. The curve for the temperature coefficient is characteristic of alloys which are solid solutions. The Hall constant [84] is evidently closely related to the thermoelectric power in agreement with the suggestion of Beattie that there is a proportionality between these two quantities.

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[81] Haken: *Ann. d. Phys.*, **32**, 291, 1910.
[82] Honda and Sone: *Sci. Repts. Univ. Tokio*, **2**, 5, 1913.
[83] Gehlhoff and Neumaier: *Verh. d. Deutsch. Phys. Ges.*, p. 876, 1913.
[84] Smith: *Phys. Rev.*, **32**, 178, 1911.

(*To be continued*)

Geographical Determination of Hexagonal and Tetragonal Crystal Structures from X-ray Data. A. W. HULL and W. P. DAVEY. (*Phys. Rev.*, May, 1921.)—The determination of the crystal structures from the diffraction patterns formed by X-rays that have traversed the substances considered is steadily proceeding. Plots abound in this paper, such as will lighten the work of the investigator in this field. In a second paper in the same journal the first of the two authors gives the results of his examination of thirteen common metals. Taking the first metal, chromium, it is stated that it has for its lattice-type the body-centered cube; that the side of its elementary cube is 2.895 angstroms; that the distance between nearest atoms is 2.508 angstroms, and finally that its density calculated from X-ray comes out 7.07, while its value by experiment 6.92.

G. F. S.

Colorimetric Determination of Hydrogen Ion Concentration.—In the determination of the hydrogen ion concentraction in liquids colorimetrically by means of indicators, an indicator is usually added to several cubic centimetres of the liquid. LLOYD D. FELTON, of Johns Hopkins University (*Journ. Bio. Chem.*, 1921, xlvi, 299–305), has devised a procedure by which the hydrogen ion concentration may be determined, using only a few drops of the liquid. Several individual drops of the liquid are placed on a white porcelain plate, and a drop of a different indicator solution is mixed with each drop of the liquid. The resulting color shows the hydrogen ion concentration of the liquid. In order to increase the range of each indicator solution, and thereby to decrease the number of indicator solutions required, Felton recommends use of double indicators; a solution is prepared containing two indicators which show opposite color changes; the color of one indicator is intensified in solutions of increasing hydrogen ion concentration, while the color of the other indicator is intensified in solution of decreasing hydrogen ion concentration. Such double indicators and their range for hydrogen ion concentration (pH) are: thymol blue plus bromphenol blue pH 1.2 to pH 4.6, methyl red plus bromthymol blue pH 4.6 to pH 7.6, methyl red plus bromcresol purple pH 4.6 to pH 7.0. A mixture of methyl red and thymol blue may be used for rough determinations of hydrogen ion concentration between pH 4.6 and pH 9.0. The determination may always be rendered more accurate by comparison of the colors obtained in the determination proper with colors yielded by the indicators when mixed with buffer solutions of known hydrogen ion concentration.

J. S. H.

Chemistry of Ink.—A study of this subject has been made by C. AINSWORTH MITCHELL (*Analyst*, 1921, xlvi, 129–135). Iron gall ink contains a soluble ferrous tannate. In the process of drying, this compound undergoes a gradual oxidation and changes first into colloidal, then into insoluble tannates of iron. This oxidation is accelerated by the presence of certain catalysts, but may be arrested if the solution be sufficiently acid. Addition of acids, such as sulphuric acid, oxalic acid, or, preferably, hydrochloric acid, within certain limits preserves the ink as a stable solution or colloidal suspension. When the ink is used, evaporation occurs, and an insoluble, resinous iron tannate is formed. Iron gallate inks, which are manufactured from ferrous sulphate (copperas) and gallic acid, are stable liquids, and therefore do not require the addition of acids as preservatives. If ink be placed in bottles of "alkaline" glass, the alkali gradually dissolves in the ink, changes the color of the latter, and causes a deposition of the pigment.

J. S. H.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

SOME FACTORS AFFECTING THE LIFE OF MACHINE GUN BARRELS.[1]

By W. W. Sveshnikoff.

[ABSTRACT.]

STAR-GAGE measurements made on six machine-gun barrels at various stages of firing indicate that when the life limit is reached exhaustion is due to a combination of the abrasive action of the bullet and the abrasion by hot gases.

The author's experiments using the electric arc show that the rapid cooling (which is due to the large mass of cold metal near the highly heated inner surface of the steel) from temperatures near the melting point of the metal produces a martensitic layer. A similar layer is produced in firing of a machine gun, indicating that the temperature conditions for development of martensite by the electric arc are similar to those in the gun under actual fire.

The selective hardening of the steel sets up surface strains, and the surface of the bore is readily cracked on account of the dimensional changes of the hardened brittle surface of the steel resulting from sudden changes in temperature between separate shots. The cracks originate at irregularities in the surface of the bore, attributable to the method of manufacture of the barrels.

TESTS OF CENTRIFUGALLY CAST STEEL.[2]

By George K. Burgess.

[ABSTRACT.]

THE production of metal castings by the centrifugal process for certain non-ferrous metals and cast-iron shapes may be said to have passed beyond the experimental stage. In the case of steel

* Communicated by the Director.

[1] Technologic Paper No. 191.

[2] Technologic Paper No. 192.

very little appears to have been published regarding the properties of the metal thus cast.

Opportunity was given to the Bureau of Standards to examine in detail the physical and chemical characteristics of six centrifugal castings made by the Millspaugh process. The results are interesting in showing what may be expected from such metal as compared with the product of the more familiar manufacturing processes. The advantages to be expected from centrifugally cast steel are physical soundness and freedom from chemical segregation and thus the elimination of waste metal to be discarded, which last is always a very important factor in other processes of manufacture. For certain shapes forging and boring operations may be eliminated. The investigation shows that highly satisfactory castings which are physically sound and free from serious segregation may be produced by the centrifugal method. It is shown that the properties of these castings can be improved greatly by subsequent heat treatment such that the metal may be put in a condition to compare favorably with metal that has been forged.

A Study of the Radiation from the Vault of the Sky.—J. VALLOT. (*Comptes Rendus,* May 9, 1921.) From his success in calibrating the Arago actinometer the author has been able to undertake this investigation, which was carried out at Nice. The whole flux of radiation above the surface of the earth at any time of day is the sum of three constituents, the direct radiation from the sun, the radiation from the earth itself and that from the sky. The sum of the two last contributions amounts to about one-third of the direct radiation, taking an average throughout the year, while the vault of the sky furnishes one-fourth as much as comes direct from the sun. Of the total flux the earth is the source of about 7 per cent. Of course the results would be quite different in a climate less delightful than that of the Riviera, or even there, if all days were considered and not only those without cloud.

G. F. S.

Utah's Lofty Mountains.—Utah has many lofty mountain peaks. Six of them rise more than 13,000 feet above sea level and nearly sixty rise above 12,000 feet, according to the United States Geological Survey. The highest mountain in the State is King's Peak, which has an elevation of 13,498 feet. Mount Emmons and Gilbert Peak, both in Utah, are also high mountains, reaching elevations of 13,428 and 13,422 feet, respectively.

NOTES FROM NELA RESEARCH LABORATORY.*

COLOR TEMPERATURE OF HIGH EFFICIENCY LAMPS.

By W. E. Forsythe.

THE efficiency and life of incandescent lamps depend upon the temperatures at which they are operated, the efficiency being greater for high temperatures and life shorter. Lamps are therefore operated at temperatures which will give the desired life. The integral color of the light given by the lamp also depends upon the temprature, the light being bluer for the higher temperatures.

It has been found by experiment that the light from incandescent lamps can be matched in color with that from a black body at some particular temperature, which temperature is called the color temperature. Making use of this fact, the quality of the light given by the different lamps can be given by its color temperature.

This color matching can be done quite accurately by the use of an ordinary Lummer-Brodhun contrast photometer. It is sometimes difficult to operate a black body of sufficient size at high enough temperatures, so that its luminous flux will match in color that of higher efficiency Mazda C lamps. For this reason different means are employed in obtaining the color standards for high temperatures. The standards of color used in obtaining the color temperature of the Mazda C lamps were obtained by measurements with a pyrometer of the relative brightness in limited parts of the red and blue ends of the spectrum of both the color standard and the black body. By this method a smaller black body at higher temperature can be used. The color standard and the black body are at a color match when they both have the same ratio of red to blue brightness.

Several different kinds and types of incandescent lamps operated at certain efficiencies have been color-matched with a black body and the results are given in Table I.

The true temperatures given are the actual temperatures of a portion of the filament far enough removed from the ends so that

* Communicated by the Director.

it is at the maximum temperature, while the color temperatures are for the lamp taken as a whole.

Lamp	W. P. S. C. P.	Temperatures Degrees K	Color Temperature
50-Watt Carbon	3.76	2115[1]	2156
50-Watt Gem	3.1	2180[1]	2195
50-Watt Tantalum	2.56	2160[2]	2260
40-Watt Mazda B	1.36	2410	2460
100-Watt Mazda C	1.00	2745	2740
500-Watt Mazda C	0.72	2835	2880
1000-Watt Mazda C	0.62	3010	2985
1000-Watt Stereopticon	0.52	3185	3175
900-Watt Movie	0.46	3290	3220

These temperatures are based upon the assumption of Wien's equation with c_2 taken as 14,350μ degrees and upon the melting point of gold taken as 1336° K. On this scale the melting point of palladium has been found to be 1828° K. For convenience in the calibration of optical pyrometers, a black body held at the melting point of palladium is used as the point of reference.

Cleveland, Ohio,
June, 1921.

COLLOIDAL METALS AND BIOLUMINESCENCE.

By E. Newton Harvey.

(Physiological Laboratory of Princeton University. From experiments carried out at Nela Research Laboratories.)

LIGHT production by animals is due to the oxidation of a substance, luciferin, in the presence of an enzyme or catalyst, luciferase, water, and oxygen. Oxyluciferin is the oxidation product and this may be reduced to luciferin again by appropriate methods. Although luciferin from a small crustacean, *Cypridina*, will oxidize spontaneously in presence of oxygen without luciferase, it does not luminesce under these conditions, but only gives light if the catalyst is present.

For some years efforts have been made by the author to find an organic or inorganic catalyst of known composition which

[1] True temperature calculated from brightness temperature, assuming an emissive power of 80 per cent.

[2] True temperature calculated from brightness temperature, assuming an emissive power of 48 per cent.

might take the place of the luciferase produced by *Cypridina*. The search has run in three directions:

1. The testing of various plant and animal extracts known to contain oxidizing enzymes;

2. The testing of well-known oxidizing agents, like H_2O_2, ozone, permanganates, bichromates, etc.; and

3. The testing of true oxidative catalysts, such as the salts of certain heavy metals and colloidal metal solutions, especially metals of the platinum group.

By courtesy of the Nela Research Laboratories, samples of many different metals were obtained and colloidal solutions prepared by the Bredig arc method. Samples not already in the form of wire or rod were prepared as rod by one of the physicists of the laboratory. Sols in distilled water, n/2000 NaOH, or weak albumin solution, were obtained with platinum, palladium, rhodium, iridium, ruthenium, vanadium, gold, silver, nickel iron, cobalt and copper. Some of these formed hydroxid sols; others presumably existed as suspensoids of metal particles. Not one of these solutions produced light when mixed with luciferin. They therefore will not act as catalysts for the reaction

$$\text{luciferin} + O = \text{oxyluciferin}$$

Although negative, these results are perhaps worthy of record as further evidence for the specificity of *Cypridina* luciferase. Thus far the author has found no substances capable of taking the place of luciferase in the oxidation of luciferin, although hundreds of extracts of non-luminous animals or plants and various organic and inorganic oxidizing agents have been tried. It should, perhaps, be pointed out that the luciferin of certain luminous animals can be oxidized with light production by extracts of non-luminous animals, and by oxidizing agents. This has been demonstrated by Dubois for *Pholas*, a luminous mollusc. It is not the case in *Cypridina* and certain evidence the author has been accumulating indicates that the luciferin of *Cypridina* cannot be made to luminesce by luciferase from some other luminous animals. The reaction is, therefore, specific to a high degree and future work, on which the author is now engaged, may indicate a species and genus relationship among the luciferases similar to that among the precipitins.

May, 1921.

TEMPERATURE VARIATIONS IN THE EMISSIVE POWER OF GOLD IN THE VISIBLE SPECTRUM.

By A. G. Worthing.

RESULTS here reported refer to polished gold which has been annealed by heating to a temperature of about 1250° K for several minutes.

Two methods, both making use of the disappearing-filament pyrometer, have been employed. The first method is the same as that used by the author in a similar study of tungsten. It consisted in comparing the brightness of the surface of an incandescent tubular filament of gold with that of its black-body interior as seen through a small hole in the filament wall. The second method is similar to the common method of measuring reflectivity. It consisted essentially in comparing the brightness of a light source with that of its image in a polished-gold surface.

The results at room temperature are in good agreement with those obtained by Hagen and Rubens. For the three wave-lengths, 0.66μ, 0.53μ and 0.47μ, respectively, 0.10, 0.36 and 0.63 have been obtained. At 1300° K the corresponding values are 0.18, 0.47 and 0.63. Thus, with increase in temperature there is a great increase in the emissive power in the red end of the spectrum, a relatively smaller increase in the green portion, and no appreciable change whatever for the blue light corresponding to 0.47μ.

These results show the behavior of gold on heating to be exactly similar to that found for tungsten in the near infra-red by Weniger and Pfund. Corresponding to 1.27μ for tungsten, the wave-length at which they found no change on heating, we have 0.47μ as the analogous wave-length for gold.

June 21, 1921.

Atomic Weight of Lanthanum.—By the analysis of lanthanum chloride, Gregory P. Baxter, Muneo Tani, and H. C. Chapin, of Harvard University (*Jour. Am. Chem. Soc.*, 1921, xliii, 1080–1085), have obtained a value of 138.91 as the atomic weight of lanthanum.

J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE BASIC AMINO ACIDS OF GLYCININ, THE GLOBULIN OF THE SOY BEAN, SOJA HISPIDA, AS DETERMINED BY VAN SLYKE'S METHOD.[1]

By D. Breese Jones and Henry C. Waterman.

[ABSTRACT.]

THE monoamino acids of glycinin have been determined in a hydrolysis by Osborne and Clapp, who determined also the hexone bases by the direct isolation method of Kossel and Kutscher. Cystine was not isolated. No determination of the basic amino acids by the more recent method of Van Slyke seems to have appeared. Glycinin, prepared in accordance with the procedure of Osborne and Campbell, was analyzed by Van Slyke's method, the phosphotungstates of the bases being decomposed by the amyl-alcohol and ether method.

The percentages of the basic amino acids, calculated on the basis of the moisture and ash-free protein, were found to be as follows: Arginine, 8.07; cystine, 1.18; histidine, 1.44; lysine, 9.96; ammonia, 2.28. The Kossel and Kutscher figures given by Osborne and Clapp are as follows: Arginine, 5.12; cystine, not determined; histidine, 1.39; lysine, 2.71; ammonia, 2.56. The tryptophane, calculated according to Gortner's observation that 86.5 per cent. of the tryptophane N is converted into humin N on hydrolysis in the presence of carbohydrate, is 1.37 per cent. of moisture and ash-free protein. This figure is to be regarded as minimal, since no carbohydrate, except that occurring as an impurity in the preparation used, was present in the hydrolysis. The Van Slyke analyses were made in duplicate and agreed well throughout.

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* Communicated by the Chief of the Bureau.

[1] Published in *J. Biol. Chem.*, Vol. 46, No. 3 (1921), pp. 459-462.

SOME SYNTHETIC RESINS FROM FURFURAL.[1]

By Gerald H. Mains and Max Phillips.

[ABSTRACT.]

WITH the improvement by the Bureau of Chemistry of the processes for the production of furfural cheaply and on a large scale, resins made from it become of economic importance. The optimum conditions for the production of fusible resins suitable for use in varnishes by the condensation of furfural with amines, ketones, and other compounds were determined. It was found that eight of these resins—furfur-aniline, furfur-α-naphthylamine, furfur-o-toluidine, furfur-zylidine, furfur-acetone, furfur-methyl ethyl ketone, furfur-amide, and furfur-sodium hydroxide resins—can be produced from materials cheap enough to make it of practical importance under present conditions. The varnish stains given by these resins in benzene and furfural solutions and their appearance when applied to oak were studied.

[1] Published in Chemical and Metallurgical Engineering, Vol. 24, No. 15 (1921), pp. 661–663.

On the Gamma Radiation and the Heat Developed by Radium and Mesothorium.—MME. P. CURIE. (*Comptes Rendus*, April 25, 1921.) Radium and mesothorium are isotopic radio-active elements whose separation by chemical processes is impossible. The distinguished Professor of General Physics in the University of Paris, unabashed by the difficulties of the case, seeks a method of determining the relative quantities of the two elements in a mixture contained within a sealed tube.

Each of them gives rise to a series of derivatives, and in the process gamma-rays are given off and heat is evolved. It would be difficult to distinguish one element from the other by the penetrating power of the gamma-rays escaping from a closed tube. The development of heat within the two elements, due to the energy of the alpha-rays, is fortunately not in direct proportion to the gamma-ray radiation. For the same strength of radiation mesothorium sets free less heat than radium does. It is therefore from a study of both the gamma-radiation and of the heat production that a way is devised of calculating how much radium is in the mixture and how much mesothorium.

G. F. S.

NOTES FROM THE RESEARCH LABORATORY, WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY.*

THE ARC RUPTURE OF LIQUID DIELECTRICS.[1]

By C. J. Rodman.

[ABSTRACT.]

LIQUIDS possessing a comparatively high dielectric strength, which are non-inflammable or semi-inflammable, and which may act as a media of low viscosity, have been subjected to high-frequency arcing beneath the liquid surface. A high-potential, high-frequency generator, having a maximum potential of 100,000 volts and a frequency of approximately 330,000 cycles, was used to disrupt the oil contained within a convenient vessel between two accurately adjustable ball electrodes.

Halogenated aliphatic and aromatic hydrocarbons, as well as mixtures of these with some mineral oils, were subjected to breakdown. Finely divided and highly non-conducting amorphous carbon, saturated and unsaturated hydrocarbons lower in the series, hydrochloric acid (from chlorinated compounds) and a number of gases were obtained. These gases consisted chiefly of hydrogen and unsaturates with small amounts of carbon monoxide, carbon dioxide, methane and nitrogen.

With an increase of halogenation of the oils a decrease in gas eliminated per K. W. sec. arc rupture was noted. The normal amount of gas obtained per K. W. sec. from a mineral oil was approximately 65 c.c., whereas that volume obtained from a highly chlorinated oil was as low as 20 per cent. of that amount. The gas obtained in the latter case is non-explosive when ignited with air mixtures.

The liquid dielectrics are apparently broken down by a temperature pressure effect of very short duration, rather than by the sympathetic vibration and rearrangement of the compounds by high frequency alone.

* Communicated by the Manager.

[1] Scientific Paper No. 103.

Grindstones and Pulpstones.—According to reports submitted to the United States Geological Survey, 44,832 tons of grindstones, valued at $1,239,990, were sold in 1920. The sales in 1919 amounted to 40,755 tons, valued at $993,959. This material was produced from sandstone quarries in Michigan, Ohio, and West Virginia. The sizes of the grindstones vary greatly and are reported as square grindstones, from ¼ inch to 8 inches in diameter, and as lathe stones, from 6 to 12 inches in diameter, and as grindstones, from less than a foot in diameter and less than a pound in weight to large stones 6 to 7 feet in diameter, 8 inches to a foot or more in thickness, and from 1 to 2 tons in weight. The prices of the stones differ according to the size and quality of the stone. The smaller sized stones, which are sold by the piece, show a much higher average value per ton than the large stones. The ordinary sizes were reported to range from $23 to $40 per ton f.o.b. (unmounted) at the quarry. The average value per short ton, of all the grindstone material sold in 1920 was $27.66; the average in 1919 was $24.39.

Pulpstones are heavy stones used for grinding wood into fine fibre for making pulp and paper. These stones are generally 54 inches in diameter and 27 inches thick and weigh about 2 tons, but some machines require stones 62 inches in diameter, 54 inches thick, and that weigh about 4 tons. The production in 1920 was 8652 tons, valued at $467,014, and in 1919 it was 6110 tons, valued at $342,056. The average value per ton was $54 in 1920 and $56 in 1919. Pulpstones were obtained from quarries in Ohio and West Virginia.

Business conditions in this industry were unsettled throughout the year, and though the demand was good the sales were lessened by difficulties with transportation and with labor.

Corrosion of Boiler-tube Due to Carbonic Acid.—B. G. Worth presented to the 39th general meeting of the American Electro-Chemical Society a paper describing an unusual corrosion of a steam boiler. All attempts to control the action by electrolytic means failed. The chemist at the plant found that a notable quantity of ferrous carbonate was held in solution by excess of carbonic acid, which is a not-infrequent condition in ground waters. It is rather remarkable that the water-softening plant was not originally adapted to deal with this condition, as it is generally evident by the change of the water from clear to a reddish turbidity on standing a short time exposed to the air, and still more quickly if aerated. Corrosion of metals by natural waters has been a subject of extensive study, and among other conditions a water containing much dissolved air, with very little scale-forming material will often produce notable corrosion, especially if the feed water is introduced by a tube terminating at the boiler wall. The corrosion is generally less if the tube is prolonged to, or near, the centre of the water-mass. H. L.

NOTES FROM THE U. S. BUREAU OF MINES.*

PRINCIPLES GOVERNING PRODUCTION OF OIL WELLS.

By Carl H. Beal and J. O. Lewis.

THE factors governing the production of oil are extremely variable. Many of them can be studied and their influence on production determined, whereas the effects of others can only be estimated. Since most of the factors are interrelated and affected by each other, many conclusions can be derived only by studying wells where one factor is stronger than the others. Some of the factors that control the oil content in a sand affect also the amount that can be recovered and the rate at which it may be obtained. The main natural influences that control production are the oil content of the sand, resistance to movement of oil through the sand, the expulsive forces and their effectiveness. The chief artificial factors are the spacing of wells, operation of the wells, and the application of stimulative processes.

Oil content is determined by the thickness, porosity, extent, and sometimes the saturation of the oil sand. The resistance depends chiefly on the porosity, size of sand grains, and viscosity of the oil. The expulsive forces are the compressed gases, the direct water pressure, and gravity. All these are interrelated in effect as regards the ultimate production, and control the manner and rate of oil flow. Their influence on oil content, ultimate production, and decline are discussed in Bulletin 194, recently issued by the Bureau.

PERMEATION OF OXYGEN BREATHING APPARATUS BY GASES AND VAPORS.

By A. C. Fieldner.

TESTS were made to determine the permeability of the rubber bags of oxygen breathing apparatus to gases and vapors. As the bags showed dangerous penetration in vapors of volatile gasoline, further tests were made with separate pieces of fabrics in a special

* Communicated by the Director.

apparatus for two-hour periods, which is the time that the larger breathing apparatus is designed to be worn. All the fabrics now used by the Bureau for breathing bags proved penetrable to gasoline and benzene vapors, except one of heavy sheet rubber one-sixteenth inch thick. Also, a fabric made of two rubberized sheets cemented with a glue and glycerin mixture proved impermeable, and a fabric made of cloth impregnated and coated on one side with pyroxylin varnish showed only slight penetration. Final recommendations regarding the use of heavy rubber, glue-glycerin, or pyroxylin fabrics in breathing bags will depend on results obtained in actual use of these fabrics during the coming year in oxygen-breathing apparatus used by the Bureau.

The tests were initiated because of the death of a member of the Bureau in a gasoline tank while wearing oxygen breathing apparatus. They are more fully described in Technical Paper 272 of the Bureau, by A. C. Fieldner, S. H. Katz, and S. P. Kinney.

EFFECTS OF CRYSTALLINE PARAFFIN WAX ON VISCOSITY OF LUBRICATING OIL.

By E. W. Dean and L. E. Jackson.

ONE of the refining processes to which lubricating oils are frequently subjected effects a reduction in content of paraffin wax. The actual treatment usually involves chilling and filter pressing; the most important result accomplished from a commercial point of view is lowering of the "cold test" of the oil. The Bureau of Mines recently had occasion to ascertain the effect of changes in paraffin wax content upon the viscosity of oil and has conducted a series of experiments.

The Bureau of Mines' method for the analysis of crude petroleum, which includes determination of the viscosities of lubricating oil distillates, does not provide for preliminary removal of paraffin wax, and it has seemed advisable to determine whether this omission causes any important variation from the results that would be obtained through commercial refinery processing. It was also thought that the tests might be of some value in indicating the general effect of paraffin content upon one of the most important properties of lubricating oil.

The results indicated that the changes in content of paraffin wax cause negligible variations in the viscosity of the commercial oils, and that the value of the Bureau of Mines' method for determining the viscosity of vacuum distillation fractions from crude oil apparently is not affected by the fact that paraffin wax is not separated from the products that are tested. The tests are more fully described in a recent report (No. 2249) issued by the Bureau in mimeograph form.

HIGH-GRADE TALC AND THE CALIFORNIA TALC INDUSTRY.

By Raymond B. Ladoo.

HIGH-GRADE prepared talc may be divided into two classes dependent upon use—(1) massive talc, used for lava gas-burner tips and electrical insulation, pencils, tailors' chalk, etc.; and (2) ground talc used for toilet powder. Talc of the first class, suitable for lava, is not common in this country, and has been mined in only a few localities. Talc which may be cut into crayons, tailors' chalk, etc., is more widely distributed. The production of high-grade white talc suitable for the manufacture of toilet powder is a problem which requires considerable attention. Until the last few years most of the toilet-grade talc consumed in this country was imported. A small, irregular production was obtained from North Carolina, Georgia and Virginia, but this material fluctuated so greatly in quality and quantity that it was not largely used by manufacturers of high-grade toilet powders. Deposits of high-grade talc in California have been known for some years and the war caused a remarkable increase in production from 630 tons in 1916, to 4152 tons in 1917. In 1918, California stood third in the list of talc-producing States. In the essential qualities of pure white color, freedom from grit, and fine grain size it is a well established fact that the best California talcs equal or surpass the best imported talcs. In the debatable qualities of slip and freedom from lime, some of the best California talcs equal some of the best imported talcs and in other cases excel other imported talcs. Some of the very largest consumers of toilet-grade talc have expressed complete satisfaction with the high-grade California talcs and have used them regularly in preference to Italian talc.

Therefore, it can not be truthfully said the United States produces no talcs equal in quality to imported talcs. Unfortunately many domestic consumers have been so thoroughly imbued with the alleged superiority of imported talcs that domestic talcs have not been given a fair chance. In order to make the domestic product better known, the Bureau has issued a short report on the subject.

On the Displacement of Solar Rays Under the Action of Gravitation.—H. BUISSON and CH. FABRY. (*Comptes Rendus*, April 25, 1921).—The Theory of Relativity predicts a shifting of the rays of the solar spectrum towards the red, in comparison with the same rays emitted by artificial sources. This is due to the gravitational field of the sun. Each wave-length should be lengthened by a little more than two-millionths of its terrestrial value.

As long ago as 1896, Rowland and Jewell, at Johns Hopkins, found that there was a difference between the measured lengths of the same lines obtained in one case from the sun and in the other from the electric arc. In most instances the lengths of the solar waves were the greater, though the opposite occurred also. In 1909, the authors showed that these latter anomalies disappeared when comparisons were made with light emanating from an arc in a vacuum. At that time pressure was the sole cause known to be competent to produce a general shifting of the rays. Earlier in the present year Perot has shown that the *b* line of magnesium displays no noticeable shift due to pressure, and that the difference between its two wave-lengths according to solar or terrestrial origin agrees well with the predicted Einstein value.

The authors discuss 32 similar differences for as many iron lines, and conclude that they all similarly are in accord with the predicted values within the limit of experimental error. Thus, on the hypothesis that the pressure in the reversing layer of the sun is so small that it causes no shifting of the lines, it appears that the Einstein effect is competent to explain the difference between the wave-lengths of the lines derived from the sun and from earthly sources.

G. F. S.

THE FRANKLIN INSTITUTE.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, June 1, 1921.)

HALL OF THE INSTITUTE,
PHILADELPHIA, June 1, 1921.

MR. CHARLES W. MASLAND *in the Chair.*

The following report was presented for final action:

No. 2769: Variable Pressure Viscometer. The Certificate of Merit to Prof. Eugene C. Bingham, of Easton, Pennsylvania, and Mr. Henry Green, of Palmerton, Pennsylvania.

The following report was presented for first reading:

No. 2773: Photo-Elastic Method of Determining Stress.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, June 8, 1921.)

NON-RESIDENT.

MR. GEORGE EDWARD BUXTON, 322 King Street, Pottstown, Pennsylvania.
MR. GEORGE E. CABOT, Middle Road, Montecito, Santa Barbara, California.
MR. EARL H. TSCHUDY, 7 South Fourth Street, Minersville, Pennsylvania.

CHANGES OF ADDRESS.

MR. JUDSON T. BALLARD, 1010 Chelten Avenue, Oak Lane, Philadelphia, Pennsylvania.
MR. THOMAS BILYEU, 697 E. Broadway Street, Portland, Oregon.
MR. EDWARD L. CLARK, Commercial Truck Company, Hunting Park and Rising Sun Avenues, Philadelphia, Pennsylvania.
MR. HOWARD N. EAVENSON, 4311 Bayard Street, Pittsburgh, Pennsylvania.
MR. BYRON E. ELDRED, 66 Myrtle Avenue, Flushing, Long Island, New York.
DR. JACOB S. GOLDBAUM, 4234 Spruce Street, Philadelphia, Pennsylvania.
MR. D. B. HEILMAN, Bernharts, Pennsylvania.

DR. A. E. KENNELLY, in care of Morgan, Harjes & Cie, 14 Place Vendome, Paris, France.

PROF. W. LASH MILLER, 8 Hawthorne Avenue, Toronto, Canada.

MR. J. MILLIKEN, President, Industrial Car Manufacturers' Institute, 68 William Street, New York City, New York.

DR. P. G. NUTTING, 848 First Street, Ocean City, New Jersey.

MR. JOHN C. PENNIE, Pennie, Davis, Marvin & Edmonds, 165 Broadway, New York City, New York.

MR. C. E. POSTLETHWAITE, Pressed Steel Car Company, 55 Broad Street, New York City, New York.

PROF. MONROE B. SNYDER, 111 Grand View Road, Ardmore, Pennsylvania.

MR. FRANK J. SPRAGUE, Sprague Safety Control and Signal Corporation, 421 Canal Street, New York City, New York.

NECROLOGY.

Henry Spencer Blackmore was born at Yonkers, New York, on March 10, 1868, and died at Duanesburgh, New York, on February 16, 1921. He was educated in the public schools of Mt. Vernon, New York, and in 1884 entered the New York College of Pharmacy, from which he was graduated four years later. He devoted his time to chemical investigations and devised new processes for reducing aluminum and other metals, for making alkali, caustic soda and sulphuric acid. He improved methods for the manufacture of cyanides, ammonia, alcohol, ketones, lithium salts, etc., more than 150 patents having been granted him for his various inventions. He was a member of the Chemical Societies of the United States and Great Britain. Mr. Blackmore became a member of the Institute on March 26, 1897.

Mr. Wm. B. Cogswell, Solvay Process Company, Syracuse, New York.

Mr. Joseph C. Fraley, 1815 Land Title Building, Philadelphia, Pennsylvania.

Mr. Joseph B. Rohrman, 15 Aronimink Place, Drexel Hill, Pennsylvania.

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BOOK NOTICES.

A FRENCH-ENGLISH DICTIONARY FOR CHEMISTS. By Austin M. Patterson, Ph. D. xvii-384 pages, 12mo. New York, John Wiley and Sons, Inc. 1921, $3.00 net.

Living languages grow so fast that even those who speak them cannot always keep up with the supply of new words, and still more difficult is it for foreigners to do so. The success of Dr. Patterson's German dictionary has been so marked that it is certain that he knows the principles of dictionary making, and we are not surprised to find that the present work is a most satisfactory production. The war has enriched all the more important languages with a host of terms, many of them derived from those already existing in the given languages, but many others borrowed from other tongues with more or less alteration that the exigencies of spelling and pronunciation involve. English-speaking peoples have long been familiar with the "rosbif" and "biftek" of the French restaurants, and some English words unchanged in spelling but probably much changed in utterance are now among the familiar sights in newspapers and scientific journals. "Sport," "film-pack," "roll-film" are examples.

Dr. Patterson's book will be welcome to all chemists who are called on to translate from the current literature. It contains an enormous amount of information, which is set forth in a most convenient form by the manner in which the book is printed, the type used being clear and distinct. A good deal of useful information is given in the introduction concerning the equivalencies of terminations of chemical compounds in the two languages. It is pleasing to note that the author has advised against the literal translation of the French names for salts, recommending that *"carbonate de soude"* should be rendered "sodium carbonate." Chemistry is much indebted to the group of French chemists who in the later years of the eighteenth century established a system of nomenclature which has been found to be fairly capable of expansion, but it is much to be regretted that in carrying it over into English the unnecessary "of" was retained. The work before us will meet with the same success that the author's previous German-English Dictionary received.

HENRY LEFFMANN.

La Théorie de la Relativité Restriente et Gn'ralisée, Mise à la Portée de Tout le Monde. By A. Einstein; Traduit par Mlle. J. Rouvière. Pp. xxii-120, 12mo.

This is a French version, without any changes, of the text of the tenth German edition of Einstein's excellent and well-known booklet, of which an English translation appeared in 1920. The present publication contains a valuable preface by the well-known mathematician, Professor E. Bovel, and this will perhaps attract even those French-speaking English readers who have already acquainted themselves with the English version of Einstein's

popular presentation of his own theories. However, Mlle. Rouvière's charmingly fluent language will certainly repay the time spent on re-reading this booklet.

LUDWIK SILBERSTEIN.

THE ANALYST'S LABORATORY COMPANION. By Alfred E. Johnson, B.Sc., London. F.I.C., A.R.C., Sc.I. Fifth edition, ix–176 pages, including index. 12mo. Philadelphia, P. Blakiston's Son and Company. $3 net.

This is a collection of the usual tables for use of chemists. The author has in this edition re-calculated tables according to the international atomic weights published in 1921. The beer-analysis section has been much altered and enlarged, new tables, derived from official sources, for determining the original gravity of beer have been inserted in the place of the tables long appearing in English works. Such tables have probably been of more importance in England than in the United States and the condition is still more accentuated to-day.

The preface gives in considerable detail, the improvements which have been made, and the work in its present form will be of much use to the chemist.

HENRY LEFFMANN.

THE COMMERCIAL PHOTOGRAPHER. By L. G. Rose, former photographer for the National Geological Survey and for the U. S. Naval Gun Factory. 145 pages, index and 89 illustrations, quarto. Philadelphia, Frank V. Chambers, 1920.

The Commercial applications of photography are many sided at the present day, and the high technical skill which has been developed, both in the production of the negative and print and the making of the photogravure, has given rise to a most extensive field of work, which this book covers. The text and illustrations are principally a reprint from articles in the *Bulletin of Photography*. The author's long and varied experience qualifies him to make an excellent work, and he has accomplished this task in the volume before us. The theories of photographic procedures have been left unconsidered, and very wisely, for they are not necessary to the purposes of this book and besides, are still in many cases undecided. One has only to read the recent discussions on the nature of the latent image to see how incomplete is our knowledge of the chemistry of photography.

The volume is abundantly illustrated with photogravures of exteriors, interiors, shop and residence rooms, articles of merchandise, posters and examples of the treatment of plates that have been, by accident, wrongly exposed. Many forms of apparatus used in photography are described and shown. The photogravures have all the excellence that is so striking a feature of the *Chambers Press*, and the paper and type are fully equal in quality to the pictures. To most persons the book will appeal as a work of art, but to those who are concerned with the field to which it is devoted it will be a manual rich in information and guidance.

HENRY LEFFMANN.

COCOA AND CHOCOLATE. THEIR CHEMISTRY AND MANUFACTURE. By R. Whymper, 2nd edition, revised and enlarged. 8vo., xxi, 552 pages, contents, index, 16 plates and 38 figures in text. Philadelphia, P. Blakiston's Son & Co. $10.00 net.

This book presents a thorough and highly interesting study of the chocolate plant. Linnæus, in 1720, gave the now well-known botanical name *Theobroma cacao*, the generic name being derived from Greek words, usually rendered "food of the gods," though the exact translation might be "god food." There are several other species, some of which seem to be suitable as sources of chocolate. The author has taken pains to prevent confusion in nomenclature, for there are three important plants, the names of which are so much alike as to easily lead to error. The "coconut" (which is often incorrectly spelled "cocoanut") is from the *Cocos nucifera*, a palm far different in character composition and botanical relationship from the chocolate nut. Then, there is *Erythroxylon coca*, from which cocaine is derived and which is quite different in its nature from the other two. Mr. Whymper reserves the word "cacao" for all the forms of raw material and for the fat extracted from the bean, thus emphasizing the distinction between "cacao-butter" and "coconut oil."

Every phase of the subject is well presented. A most interesting sketch of the history of chocolate is given from which we learn that it was introduced into Europe in 1528, when Cortez returned to Spain with the spoil of his conquests. Passing over the details of the spread of the use of chocolate, over the civilized world, we are impressed by the statement (p. 22) that the United States has become the greatest consumer of the product, the importations for the year ending January 30, 1918, amounting to 180,000 tons, the value of which was over $30,000,000. Mr. Whymper has recently visited the United States and examined the cacao industries. He says that preparations are on the market that would not be considered first-class in Europe, and since much of such chocolate was sent to our allies during the war, when they were suffering from lack of their customary products, the inferior quality has tended to injure the reputation of the makers. "Chocolate factories," he says, "are springing up like mushrooms, all over the United States"; a condition which he ascribes to the introduction of prohibition, and he thinks that the improvement and extension of the chocolate industry will be an atonement for our loss of the more intoxicating beverages. It is well-known to all who have studied even slightly the chemistry of cacao, that it contains a crystalline principle, "theobromin," which is closely similar in composition to caffein.

Nearly 200 pages are devoted to the chemistry of the product and to the methods of analysis, which section is followed by an excellent bibliography. Attention is paid to every phase of the industry and the products thereof. The diseases of the plant are serious and have been extensively studied. A former Philadelphian, Dr. James Birch Rorer, has been devoting several years to the investigation of such diseases, the work having been at first undertaken in Trinidad Island, under auspices of the British Government, but he has for some time been in Equador, pursuing

the same line. The work of several other investigators is mentioned in foot notes. Canker and Black Rot are the two most serious diseases. There are also insect pests. Many pages would be needed to set forth the many interesting data in this book, which is a triumph both of scientific method and printer's skill.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 103, Performance of a 300-Horsepower Hispano-Suiza Airplane Engine, by S. W. Sparrow and H. S. White, Bureau of Standards. 22 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

A 300-horsepower Hispano-Suiza engine has been tested at the Bureau of Standards. The program of tests was planned in coöperation with the Engineering Division of the Air Service of the United States Army and was intended primarily to determine the characteristic performance of the engine at various altitudes. The engine was operated at the ground, at 25,000 feet, and at intermediate altitudes, both at full load and at loads similar to those that would be imposed upon the engine at various speeds by a propeller whose normal full-load speed was 1800 r.p.m. Friction horsepower also was determined in order that the mechanical efficiency of the engine might be calculated.

From the test data there were computed the brake horsepower; brake mean effective pressure; specific fuel consumption; mixture ratio; jacket loss; exhaust loss; and thermal, mechanical, and volumetric efficiences. A record of jacket water, temperatures, oil temperatures, manifold pressures, etc., shows the conditions under which the test was made.

A brake horsepower of 352 was obtained at 2200 r.p.m., and a maximum brake mean effective pressure of 128 pounds per square inch at about 1600 r.p.m. The mechanical efficiency varied from 88 per cent. to 83 per cent. from speeds of 1400 r.p.m. to 2200 r.p.m., while the brake thermal efficiency based on the lower calorific value of the fuel, was about 26 per cent. over this speed range. At 1800 r.p.m., and at an air density of 0.040 pounds per cubic foot the brake horsepower was about 42 per cent. and the indicated horsepower about 47 per cent. of that at the ground.

Report No. 106, Turbulence in the Air Tubes of Radiators for Aircraft Engines, by S. R. Parsons, Bureau of Standards. 13 pages, illustrations, diagrams, quarto. Washington, Government Printing Office, 1921.

The existence of turbulent flow in the air passages of aircraft radiators and of variations in character or degree of turbulence with different types of construction is shown by the following experimental evidence:

1. Pressure gradients along the air tubes are roughly proportional to the 1.7 power of the speed, which is characteristic of turbulent flow in long circular tubes of the same diameter.

2. The surface cooling coefficients of radiators vary widely (0.002 to 0.007) when expressed as heat dissipated per unit time, per unit cooling surface, per unit temperature between air and water, and at a given average linear speed through the tubes.

3. A fine wire, electrically heated, shows different cooling coefficients in the air tubes of different radiators.

4. Temperature gradients in the air tubes are of the form characteristic of turbulent flow and fail to show sudden breaks such as might indicate a dividing line between regions of viscous and of turbulent flow.

The use of special devices for increasing turbulence may increase the heat transfer per unit surface for a given flow of air through the radiator but such practice decreases that flow for a given speed of flight and increases head resistance. At very low flying speeds, or in cases where the radiator is mounted in the nose of the fuselage, turbulence devices may sometimes be used to advantage.

Report No. 108, Some Factors of Airplane-Engine Performance, by Victor R. Gage, Bureau of Standards. 29 pages, diagrams, quarto. Washington, Government Printing Office, 1921.

This report is based upon an analysis of a large number of airplane-engine tests made at the Bureau of Standards and contains the results of a search for fundamental relations between many variables of engine operation.

The data used came from over 100 groups of tests made upon several engines, primarily for military information. The types of engines were the Liberty 12 and three models of the Hispano-Suiza. The tests were made in the altitude chamber, where conditions simulated altitudes up to about 30,000 feet, with engine speeds ranging from 1200 to 2200 r.p.m. The compression ratios of the different engines ranged from under 5 to 1 to over 8 to 1. The data taken on the tests were exceptionally complete, including variations of pressure and temperature, besides the brake and friction torques, rates of fuel and air consumption, the jacket and exhaust heat losses.

With the Liberty engine operating at from 500 to 2000 r.p.m., and with the Hispano-Suiza 300 horsepower operating from 1400 to 2200 r.p.m., it is found that the friction torque increases approximately as a linear function of engine speed at a given air density, and approximately as a linear function of density at a constant speed. This means that the friction horsepower increases approximately as the square of the speed. Actually the relation of torque and speed is such that the friction horsepower increases with speed raised to a power between the first and second, this power increasing with speed, approaching the square. The relation depends upon the engine design, the speed, and density of the air. Any statements as to the distribution of the friction losses are based upon incomplete evidence; the indications are however, that the pumping losses are about half of the total friction.

Report No. 110, The Altitude Effect on Air-Speed Indicators, by Mayo D. Hersey, Franklin L. Hunt and Herbert N. Eaton, Bureau of Standards. 27 pages, plate, diagrams, quarto. Washington, Government Printing Office, 1921.

The object of this paper is to present the results of a theoretical and experimental study of the effect, on the performance of air-speed indicators, of the different atmospheric conditions experienced at various altitudes. This matter has ordinarily been handled in a very simple way by following the PV^2 law and therefore correcting the observed reading of the air-speed

indicator by assuming the differential pressure developed to be directly proportional to the density and independent of any other physical property of the air.

Thermodynamic formulæ are available indicating the probable performance of Pitot tubes at high speeds where compressibility has to be considered, but all efforts which have thus far been made to arrive at a sufficiently complete formula for the Venturi tube by purely deductive reasoning have proven impracticable, on account of the difficulty of treating viscosity and turbulence. An adequate method of analysis for such problems has, however, been found in dimensional reasoning, for by this means the minimum number of experimental data needed for providing an absolutely complete inductive rather than deductive solution can be determined. In this way in the present paper the general form of the size of the instrument, its velocity through the air, and the density, viscosity, and elasticity of the medium have been derived.

The experiments reported all relate to Venturi tubes. They include water-channel experiments to determine the degree of dynamical similarity attainable between air and water and to discover whether compressibility has to be taken into account; observations in a wind stream at reduced pressure, *i. e.*, a vacuum wind tunnel, to determine the effect of density and viscosity; airplane observations as a practical check on the laboratory results; also ordinary wind-tunnel tests.

This investigation is primarily of importance in connection with low-speed or high-altitude flight, for the altitude correction under the conditions of high-speed flight near sea level is sufficiently well given for most instruments by the simple PV^2 law.

PUBLICATIONS RECEIVED.

Rayons X et Structure Cristalline, par Sir William Bragg et W. L. Bragg, M.A. Traduit sur la troisième édition Anglaise par Mme. Mg. J. Rivière. 209 pages, illustrations, 8vo. Paris, Gauthier-Villars et Cie, 1921. Price 12 francs.

The Analyst's Laboratory Companion, by Alfred E. Johnson, B.Sc. Fifth edition, thoroughly revised, with additions. 176 pages, 12mo. Philadelphia, P. Blackiston's Son and Company, 1921. Price $3.50.

Lichttechnik, von Dr. W. Bertelsmann, Dr. Ing. L. Bloch, Dr. G. Gehlhoff, Prof. Dr. A. Korff-Petersen, Dr. H. Lux, Dr. A. R. Meyer, Oberingenieur G. R. Mylo, Reg. und Baurat W. Wechmann, Geh. Regierungsrat Prof. Dr. W. Wedding. Im Auftrage der Deutshen Beleuchtungstechnischen Gesellschaft herausgegeben von Dr. Ing. L. Bloch. 591 pages, illustrations, 8vo. München R. Oldenbourg, 1921.

Pattern-making, by Edward M. McCracken and Charles H. Sampson. 111 pages, obl. 12mo. New York, Van Nostrand Company, 1921.

Some Microchemical Tests for Alkaloids, by Charles H. Stephenson including chemical tests of the Alkaloids used, by C. E. Parker. 110 pages, plates, tables. Philadelphia, J. B. Lippincott Company.

Philosophy and the New Physics: An Essay on the Relativity Theory and the Theory of Quanta, by Louis Rougier. Authorized translation from the author's corrected text of "La Matérialisation de l'Énergie" by Morton Masins. 159 pages, 12 mo. Philadelphia, P. Blackiston's Son and Company. Price $1.75.

U. S. Bureau of Mines: Bulletin 194, Petroleum Technology 61. Some Principles Governing the Production of Oil Wells, by Carl H. Beal and J. O. Lewis. 58 pages, 8vo. Technical Paper 248, Gas Masks for Gases Met in Fighting Fires, by Arno C. Fieldner, Sidney H. Katz and Selwyne P. Kinney with a chapter on the effects of gases on men and the treatment of various forms of gas poisoning by Yandell Henderson. 71 pages, illustrations, plates, tables, 8vo. Technical Paper 288, Coal-mine Fatalities in the United States 1920 and Coal-mine Statistics Supplementing Those Published in Bulletin 115 by William W. Adams. 112 pages, 8vo. Washington, Government Printing Office, 1921.

U. S. Department of Agriculture: Bulletin No. 951, Methods for Close Automatic Control of Incubating Temperatures in Laboratories by John T. Bowen. 16 pages, illustrations, 8vo. Circular No. 171, a recently developed dust explosion and fire hazard by David J. Price. 7 pages, illustrations, 8vo. Washington, Government Printing Office, 1921.

National Advisory Committee for Aeronautics: Technical Notes No. 48, Airplane Superchargers, by W. G. Noack. 17 pages, plate, quarto. No. 49, On the Resistance of the Air at High Speeds and on the Automatic Rotation of Projectiles, by D. Riabouchinski. 8 pages, plate, quarto. No. 60, On a New Type of Wind Tunnel, by Max Munk. 19 pages, quarto. Washington, D. C., Committee 1921.

The Case for Chemical Warfare, by Sir William J. Pope, K.B.E. Reprinted from *The Chemical Age*, May 7, 1921. 8 pages, 8vo.

The Nipigon Development, by T. C. James, Assistant Engineer, Hydro-electric Power Commission of Ontario. 11 pages, plates, 8vo. Reprinted from *The Bulletin* of the Commission, January-February, 1921.

Études Elementaires de Météorologie Pratique, par Albert Baldit. 347 pages, illustration, 8vo. Paris, Gauthier-Villars et Cie, 1921. Price 15 francs.

Dry Ammonia.—According to H. W. Foote and S. R. Brinkley, of Yale University (*Jour. Am. Chem. Soc.*, 1921, xliii, 1178–1179), if dry ammonia be passed into a heavy-walled bottle, which is provided with an inlet tube and an outlet tube (each containing a stop cock) and is almost filled with anhydrous ammonium thiocyanate, this salt acts as an absorbent for the ammonia. The temperature must be kept at 0° C. As absorption occurs, a liquid is obtained. This liquid contains approximately 45 per cent. of ammonia when saturated with that gas at atmospheric pressure and a temperature of 0° C.; the absorption is extremely rapid. The ammonia may be stored in this manner, and may be drawn off in the anhydrous state through the outlet tube. The pressure at which delivery occurs depends on the temperature, and the latter is readily controlled by means of a water bath in which the bottle is placed. J. S. H.

CURRENT TOPICS.

Potash Salts in Texas.—Samples of salts recently sent from western Texas to the laboratories of the United States Geological Survey, at Washington, D. C., and of the Texas Bureau of Economic Geology and Technology at Austin, Texas, contain percentages of potash that suggest at least the richness of the potash deposits of Alsace and Germany. The samples were obtained from two borings about eighty miles apart, sunk by oil companies in the "Red Beds" region of Texas, where salt beds, red shales, gypsum, and other materials are associated in strata of nearly the same geologic age and general character as the potash-bearing beds of western Europe. The thickness of the potash-bearing beds in Texas represented by these samples is unknown, however, and the questions remain to be determined whether the deposit is thick enough to furnish potash in as great amount and of as high a grade as those in Europe, or whether it is of scientific interest only and mainly important as showing that potash-rich salts were actually deposited in this region, and that other borings in areas where similar beds occur may discover commercial deposits.

The problem of recognizing the presence of a thin bed of potash salt, of determining its thickness, and of identifying its precise position in the stratigraphic column is rather difficult, however, on account of the adverse conditions of observation, the methods of drilling, and sometimes the indifference of the driller. Among the samples recently examined was one from the Bryant well, in Midland County, Texas, which, as shown by a rough field test, is very rich in potash. Subsequent accurate determination in the laboratories of the Texas State University and of the Geological Survey in Washington showed that this sample which was saved by the driller from cuttings taken at depths between 2405 and 2525 feet contained about 9 per cent. of potash (K_2O). The sample consisted of red salt, including polyhalite, white salt, crushed red shale, and mud, so that the fragments of red salt ground up in the cuttings probably represent a layer that is richer in potash even than the sample as a whole.

A small piece of red salt brought out from a depth of about 1864 feet in the Burns No. 1 well of the La Mesa Oil Company, which is about eighty miles from the Bryant well, contained about 10 per cent. of potash (K_2O).

Adequate information as to even the probable thickness of the bed represented by the samples of potash salt is lacking for both these wells. The drill records of the La Mesa well indicate that the bed struck at a depth of 1864 feet may not be more than a

foot thick. On the other hand, the potash in the Bryant well in Midland County probably fills no more than a part of an interval of 20 feet covered by a single entry in the driller's log, and by a single sample of cuttings. Consequently, though a potash salt as good as that in Europe was laid down in Texas under probably similar conditions and at about the same time, in association with rock salt and other saline deposits, the important points yet to be determined by the drill are whether the potash deposits of western Texas are thick enough to be mined at a profit, whether we have in our own country ample supplies of relatively cheap potash for use in fertilizer, and whether these deposits possibly constitute a great potash reserve that will make the United States independent of foreign importations.

Dissociation of Hydrogen and Nitrogen by Electron Impacts. A. L. HUGHES. (*Phil. Mag.*, May, 1921.)—Langmuir found that hydrogen is dissociated by tungsten at a temperature above 1300° K. According to his calculations 84,000 calories are needed to dissociate a gram-molecule of the gas. From this it is calculated that the energy to dissociate one molecule is the energy given to one electron in falling through a potential of 3.6 volts. The present investigator set out to see whether electrons falling through this potential interval really do dissociate any molecules of hydrogen by impact. He finds that dissociation is not observable until the interval of potential reaches 13.3 volts.

The hydrogen for the experiment was contained in a glass tube jacketed with liquid air. Along its axis was a platinum strip coated with BaO and SrO. When heated by an electric current this became a source of electrons. Nickel gauze, fitting as a cylinder into the tube, served as an anode toward which the electrons were driven from the platinum cathode by an applied difference of potential. The pressure of the hydrogen ranged from .1 mm. downward. The stream of electrons was started and then readings of pressures of the gas under experiment were taken at intervals of 4 minutes. There was always a diminution of the pressure with the passage of time. For instance, to quote a single series of readings, the pressure fell from 200×10^{-5} mm. to 8.8 of the same unit in 40 minutes. The absolute change of pressure becomes smaller as the pressure of the hydrogen is reduced, but the ratio of initial to final pressure rises as the initial pressure is made smaller. As the voltage between the electrodes was raised the rate of pressure change likewise rose and reached a maximum for about 140 volts, to decline somewhat for values in excess of 150 volts.

Why does the pressure fall while the electron stream continues? The author adopts the explanation advanced by Langmuir to account for similar results which were obtained when dissociation was produced by high temperature, *viz.*, that atoms of hydrogen, resulting from dissociation, condense progressively on

the cold surface of the tube. This has at least the merit of furnishing a ready elucidation of a phenomenon which manifests itself when the experimental tube, in which the gas pressure has grown smaller owing to the electron stream, is heated, and then cooled. Upon heating the pressure rises of course, but subsequent cooling to the temperature of the bath does not reduce the pressure to its former amount when the hydrogen was at the same temperature. To cite one such experiment, pressure before the electrons passed in hundred-thousandths of a millimetre, 548; after their passage, 100; after re-heating and re-cooling, 263. It is held that, when the temperature goes up, some of the atoms of gas condensed on the cold walls get free and re-combine into molecules. When the temperature again falls these remain molecules and are not condensed as they were at the same temperature, while in atomic form.

G. F. S.

Preparation of Zirconia from the Ore.—E. C. ROSSITER and P. H. SAUNDERS describe their process for the preparation of zirconia (zirconium dioxide) from the ore in *Journ. Soc. Chem. Ind.* Trans., 1921, xl, 70–72. The ore is finely ground in a porcelain ball mill; 50 grams of the ground ore are mixed with an equal weight of sodium hydroxide; and the mixture is heated in an iron crucible with continuous stirring until a granular powder is obtained. The temperature is then raised to a just visible redness, and finally becomes approximately 600° C.; two hours are required for fusion of the mixture. While still hot, the contents of the crucible are treated with 1500 c.c. of water. The insoluble portion is collected on a filter, and is washed with water until free from alkali, then is treated with hydrochloric acid. The resulting solution contains insoluble matter, and is evaporated to dryness without filtration. The residue is extracted with hot water; the solution is filtered, and the filtrate contains zirconium oxychloride and the chlorides of certain metals such as iron, aluminum, and manganese. The solution is diluted to a volume of 1500 c.c.; and sulphurous acid is added in amount slightly in excess of that required to reduce the iron present in the solution completely to the ferrous state. Then the solution is heated to boiling, and normal sulphuric acid is added in amount theoretically required to replace the chlorine content of the oxychloride. All of the zirconium present in the solution precipitates as a basic sulphate. For quantitative results, 7 c.c. of a saturated solution of sulphurous acid and 2 c.c. of a normal solution of sulphuric acid should be used for each 0.2 gram of zirconium dioxide; and the solution containing the zirconium should be so dilute that it has a volume of at least 150 c.c. for each 2 c.c. of normal sulphuric acid to be added. If the precipitate be washed five times by decantation in a glass cylinder of 6 litres capacity, the soluble impurities are

reduced to 0.3 per cent. of the amount originally present, and less than 1 part of iron in 100,000 is present. In order to obtain zirconia, the basic sulphate may be dried and ignited; or it may be suspended in water and treated with an alkali with the production of zirconium hydroxide, the latter compound is then washed, dried, and ignited. In either case, the final product contains from 98 to 99 per cent. of zirconium dioxide; silica and a smaller amount of alumina are also present. J. S. H.

On the Supposed Weight and Fate of Radiations. SIR OLIVER LODGE (*Phil. Mag.*, April, 1921).—This, the first article in a monthly number of the great British magazine, should, in justice to the author be read in the light of the opening sentences. "In regions where our ignorance is great, occasional guesses are permissible. Some guesses occur in this paper: let an apology for them be understood.

"If light is subject to gravity, if in any real sense light has weight, it is natural to trace the consequences of such a fact. One of these consequences would be that a sufficiently massive and concentrated body would be able to retain light and prevent its escaping."

The author then works out the mathematics of the problem and draws the conclusion, "We find that a system able to control and retain its light must have a density and size comparable to

$$\rho R^2 = 1.6 \times 10^{27}$$

where ρ is the density and R the radius, both in c. g. s. units." "It is hardly feasible for any single mass to satisfy this condition; either the density or the size is too enormous." "If a mass like that of the sun could be concentrated into a globe about 3 kilometres in radius, such a globe would have the properties above referred to; but concentration to that extent is beyond the range of rational attention. The earth would have to be still more squeezed into a globe 1 centimetre in diameter." The suggestion is made that a stellar system might meet the conditions. "The question has often been asked, What becomes of all the radiation poured into space by innumerable suns through incalculable ages? Is it possible that some of it is trapped, without absorption, by reservoirs of matter lurking in the depths of space, and held until they burst into new stars? And a further more important question begins to obtrude itself: What happens to light when, in free though modified ether, it is stopped relatively to a gravitational mass? Does it retain its energy, mainly on rotational form, tie itself into electrons, and add to the mass of the body?" After an examination of this problem the author proceeds, "So if 10 cubic millimetres of earth-sunshine could be checked and condensed till its density was 10^{12} it might be converted into an electron of mass 10^{-27} gramme." G. F. S.

Phenosafranin in Photography.—Great interest has been awakened by the discovery of the strong densitizing powers of the dyestuff known commercially as phenosafranin in Europe and supplied by an American manufacturer under the title Safranin A. extra. Dr. Lüppo-Cramer, Technical Director of Kranseder & Co., Munich, whose fame in photographic research is international, called attention to the peculiar property that dilute solutions of this color have in diminishing the sensibility of exposed plates without appreciably affecting the latent image. As might be expected, many other substances have similar properties, but none so far examined equals phenosafranin. Solutions of not over one part of the color to 2000 of water are efficient, and such solution keeps. Lüppo-Cramer has further found that the dye markedly accelerates the action of hydroquinone, and that it also acts as preservative of developers. A solution of the material has recently been put on the market by an English firm under the title "Desensitol." This is a very concentrated solution, and is directed to be diluted to about fifty times for use. A. and L. Lumiere and Seyewitz have recently presented a communication to the French Photographic Society, detailing the results of many experiments to determine what other substances are densitizers. The paper has appeared in very full abstract in a recent issue of *La Revue Française de Photographie*. Lüppo-Cramer has published a small book giving an account of his researches in the field, and discussing some of the theories of the action.

H. L.

Note on the Possibility of Separating Mercury into Its Isotopic Forms by Centrifuging. J. H. J. POOLE. (*Phil. Mag.*, May, 1921.)—According to Aston's results mercury is a mixture of six isotopes having atomic weights of 197, 198, 199, 200, 202 and 204. To simplify the problem of finding on theoretical grounds whether it be possible to separate the liquid into its isotopes by centrifuging several assumptions are made. Only two isotopes are considered at present, and these have a difference in atomic weight of 4 units. They are in approximately equal amounts and are supposed to differ only in mass; all other constants being the same for both. Mercury is regarded as incompressible.

The conditions of equilibrium for such a mixture in a rotating tube placed in a centrifugal field of force are examined, and it is found that the difference of density between the two ends of the rotating tube would be only one part in 30,000 for 9000 revolutions per minute. So minute a difference could hardly be detected. It is suggested that a centrifuge could be made to run at 60,000 revolutions per minute, and that with this apparatus the difference of density would reach 1½ parts per thousand, which could be detected. After attaining this conclusion the author puts a curb on anticipation by saying: "The results obtained would apparently

hardly justify the expense entailed in constructing the special centrifuge." The analysis of elements into isotypes is based on the study of positive ray phenomena, which are not well known to chemists. If it be possible to verify the analysis by appeal to the familiar mechanical method of centrifuging, it is to be hoped that some means may be discovered for constructing the needed apparatus.

The author holds that, if liquid neon could be substituted for mercury, a difference in density ought to be obtained, since the two isotopes differ by 10 per cent. The difficulty of running at the temperature of the liquid would not be small.

G. F. S.

The Spectrum of Helium in the Extreme Ultra-Violet. H. FRICKE and THEODORE LYMAN. (*Phil. Mag.*, May, 1921.)—Hitherto investigations of the spectrum of helium in the Schumann region have been made of necessity by the use of a strong disruptive discharge, which introduced impurities into the gas through its action on the walls of the tube and on the electrodes. This state of affairs led to uncertainty in the origin to which the observed lines were to be attributed. Though other lines were believed by one investigator or another to be due to helium, yet in the range of wave-length from 1700 to 600 angstrom units only two lines could with assurance be assigned to helium. Within the last two years it has been found that there is a resonance potential for helium corresponding to a wave-length of about 600 units.

The gas was at a pressure of .8 millimetre of mercury. The current employed was direct and varied from 20 to 40 milliamperes. The vacuum spectroscope was smaller than its predecessor, the grating having a radius of only 20 cm. The change in dimensions materially reduced the absorption of light by gas. The helium as originally prepared was pure, but by the time it was transferred to the apparatus it sometimes had gained traces of hydrogen and of oxides of carbon. Under the new conditions of experiment the strongest line of all was that occurring at 585 units. Its authenticity was confirmed by experiments with the previously employed, larger spectroscope, with which the record of the line was faint but unmistakable. It is interesting to note that this line, whose existence is known by experiment, fits into the speculative scheme of Bohr and Sommerfeld.

G. F. S.

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